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ELECTRONIC AND SOLID STATE SCIENCES, PROGRAM SUMMARY FY 1976.(U)
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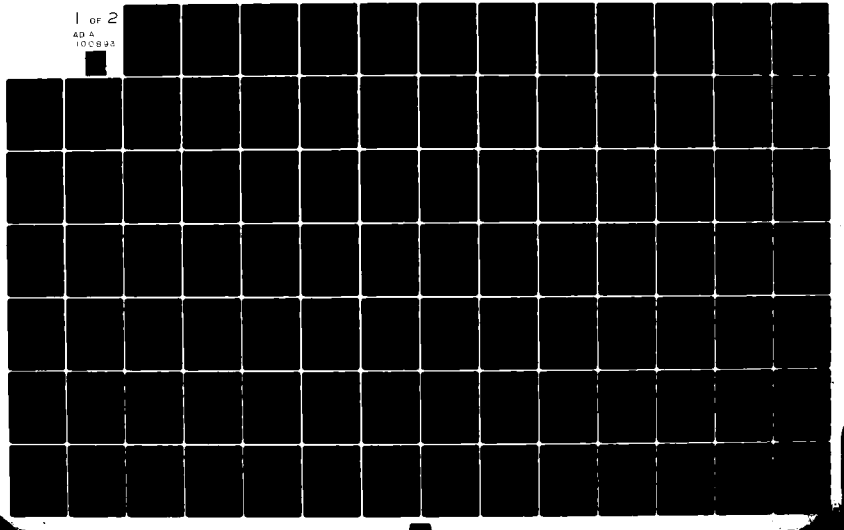

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For Further Information

This booklet represents a summary of the programs of the Electronic and Solid State Sciences Program (Code 427) for physical year 1976. Further information about these programs can be obtained, either from the Director, Dr. John O. Dimmock, at (202)692-4216, or from the scientific officers, who are:

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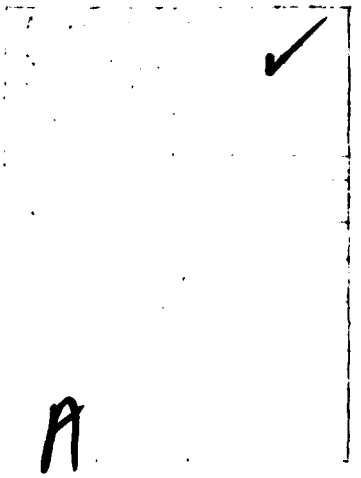

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SOLID STATE PHYSICS

RR 011-02-01, SOLID STATE PHYSICS, (Dr. D. K. Ferry, 202 692-4217)

NR 318-002, University of Pennsylvania, "Magnetic Memory Materials and Liquid Crystals", P.I. - Dr. Herb Callen, N00014-76-C-0106

It is proposed to analyze the preferential-site-ordering mechanism which determines uniaxial anisotropy in garnets. This will provide a new method of determining the dynamics and mechanism of crystal growth in such materials. Such information is needed for improving magnetic materials useful in magnetic bubble technology. Domain hardness, wall mobility and velocity saturation are among the areas to be investigated. In addition a study will be made of modern critical phenomena theory and phase transitions in liquid crystals. Progress: It was shown that the observations of Gyorgy, Sturge, and Van Uitert, on the anisotropy of Y(3-x)Lu(x)Fe5012, are in excellent agreement with the mechanism previously suggested by Callen and Akselrad. The data are consistent with a tetrahedral iron mechanism, although they do not exclude an octahedral iron mechanism. The relative contributions of the two sublattices and the relevant physical considerations have been determined. These effects are pertinent to the mechanism of preferential site ordering in these alloys. The analogy between a smectic-A liquid crystal and a superconductor is made closer by a transformation on the smectic system. Within the context of the Wilson-Fisher recursion relations, it has been shown that the critical properties of the two systems are the same, and that therefore the phase transition from smectic-A to nematic will always be at least weakly first order.

Recent Publications:

1. H. Callen, "Growth Induced Anisotropy in Garnets with Mixed Diamagnetic Rare-Earth Ions: $Y_{3-x}Lu_xFe_5O_{12}$," J. Applied Physics, Vol. 45, No. 5, pp 2348-50, May 1974.
2. T. C. Lubensky and R. G. Priest, "Critical Exponents for a Symmetric Traceless Tensor Field Theory Model," Physics Letters, Vol. 48A, No. 2, pp 103-4, June 1974.
3. H. Callen, "Thermodynamics as a Science of Symmetry," Foundations of Physics, Vol. 4, No. 4, pp 423-43, December 1974.
4. B. I. Halperin and T. C. Lubensky, "On the Analogy Between Smectic-A Liquid Crystals and Superconductors," Solid State Communications, Vol. 14, pp 997-1001, 1974.

NR 318-003, Harvard University, "Superconductors, Magnetic Detectors, and Magnetic Electronics," P.I. - Dr. Michael Tinkham, N00014-76-C-0032

Far infrared spectroscopy and laser sources are used to probe and determine the energy gaps in superconducting materials. Magnetic resonance techniques are also applied to metals and to magnetic materials. The major work is on the interaction of far-infrared laser radiation with superconducting weak-link devices. Progress: Far infrared cyclotron resonance has been observed in copper. The observed lineshapes have been analyzed with various calculations of the surface impedance change at resonance, taking into account the Fermi surface anisotropy, in addition to retardation effects and propagation effects.

Recent Publications:

J. M. Peech, "Far Infrared Cyclotron Resonance in Metals," Technical Report 9, September 1974.

NR 318-004, Clarkson College of Technology, "Magnetic Control Mechanisms at Critical Temperatures," P.I. - Dr. Earl Anderson, N00014-76-C-0051

A careful study will be made of representative samples of ferromagnetic, anti-ferromagnetic and ferrimagnetic materials in the vicinity of their magnetic transitions in order to determine the critical exponents which describe their behavior. The behavior of these different types of magnetic materials will be compared to see how they differ at the transition temperature and how they are applicable as control mechanisms in magnetic circuits. The device implications of magnetic behavior at the transition point will be surveyed. Additional magnetic materials having potential magnetic control capabilities will be sought and magnetic measurements to determine their properties carried out. Progress: A study has been made of the critical magnetic properties of lutetium iron garnet. Values of the critical exponents were observed to fulfill the scaling relationship, within the limits of experimental error. The critical temperature, obtained from the kink-point plot of applied magnetic versus break-point temperature, was reaffirmed through utilization of the Kouvel-Fisher analysis.

Recent Publications:

A. A. Stelmach, E. E. Anderson, and S. Arajs, "Magnetization of Lutetium Iron Garnet Near the Critical Point," J. Phys. Chems. Solids, Vol. 34, 1343-1346, 1973.

NR 318-005, University of Pennsylvania, "Optical and Acoustical Spectroscopy of Solids," Dr. Elias Burstein, N00014-76-C-0107

Surface electromagnetic waves and surface acoustic waves and their interaction with electrons in solids and with each other are studied to give the electrical properties of solid state materials. The interaction of surface electromagnetic waves (polaritons) with anisotropic dielectric and permeable solids will be studied via techniques such as attenuated total reflection (ATR). Progress: Surface polariton dispersion curves have been obtained for an n-InSb-air interface in a magnetic field using the ATR method and are found to be in qualitative agreement with theory. In particular, the curves show the predicted non-reciprocal nature of the surface polariton propagation, and the appearance of virtual excitation type branches of the dispersion curves. On the basis of data obtained in zero magnetic field on etched surfaces, the quantitative differences between experimental and theoretical dispersion curves are attributed to surface damage.

Recent Publications:

1. D. L. Mills and E. Burstein, "The Electromagnetic Modes of Media," Reports on Progress in Physics 37, 817-926 (1974).

2. E. Burstein, "Phase Matched Electromagnetic Generation and Detection of Surface Elastic Waves on Non-Conducting Solids," J. Appl. Physics 45, 4360 (1974).

3. E. Burstein, W. P. Chen, Y. J. Chen and A. Hartstein, "Propagating Electromagnetic Modes at Interfaces," J. Vac. Sci. Technol. 11, 1004 (1974).

4. A. Hartstein and E. Burstein, "Observation of Magneto-plasmon-type Surface Polaritons on n-InSb," Solid State Communications 14, 1223 (1974).

5. M. L. Shand, Y. L. Ching and E. Burstein, "Raman Scattering by Optical Phonons and Polaritons in CuCl," Solid State Communications 15, 1209 (1974).

6. A. Hartstein, E. Burstein, E. D. Palik, R. Kaplan, R. W. Gammon and B. W. Henvis, "Optic Phonon-Magnetoplasmon Type Surface Polaritons on n-InSb," Int. Conf. Physics of Semicond., Stuttgart 1974 (Teubner, Stuttgart, 1974) p. 541.

NR 318-007, University of Colorado, "Band Structure Modifications in Superlattice Structures," P.I. - Dr. Herbert Kroemer, N00014-76-C-0115

The effects of screening and self-energy are studied in the Peierl's instability in periodic superlattices. Work on purely electronic modifications of such instabilities is also carried out. A study of the dynamics of the motion of a Peierl's instability through its host lattice and of its high field behavior will be undertaken. A study of two-dimensional surface superlattices created by atomic steps on an off-oriented semiconductor surface will be carried out. Progress: In layer-type superlattices the electron motion perpendicular to the direction of periodicity is not quantized, a fact that greatly weakens the beneficial effects of the superlattice. The overlap of the energy bands in this structure essentially precludes the occurrence of negative differential mobility caused by a transfer of electrons between minibands. The effects seen so far in the Esaki-Tsu type structures are more likely due to modified Gunn effect. In order to realize more than just a fraction of the promise of the superlattice it will probably be necessary to prepare them in substances in which the electron motion is inherently one-dimensional

Recent Publications:

H. Kroemer, "Negative Bulk Mobility Devices - What Next?", Proceedings of the International Electron Devices Meeting, Washington, D.C., December 1974, pp 3-4.

NR 318-009, Rensselaer Polytechnic Institute, "Wave-Solid Interactions," P.I. - Dr. Harold Tiersten, N00014-76-C-0368

Theoretical investigations of the guiding of magnetoelastic and piezoelectric surface waves in deformable media and on the nonlinear interactions in acoustoelectric devices will be carried out. Progress: An analysis of the reflection of surface waves by an array of reflecting strips by means of derived approximate equations was carried out. These equations are expressed in terms of the known fundamental material constants and no measurement of model parameters is required. Agreement with experiment in Y-Z lithium niobate is good. The extremely accurate approximate solution for the fundamental nondispersive antisymmetric mode of the wedge waveguide in isotropic materials has been completed. A method of analysis has been obtained for the treatment of abrupt discontinuities in determining the influence of the radiating continuous spectrum on the propagation of elastic surface waves guided by thin films. An analysis of trapped energy resonators operating in overtones of coupled thickness-shear and thickness-twist has been completed.

Recent Publications:

1. H. F. Tiersten, "An analysis of trapped energy resonators operating in overtones of coupled thickness-shear and thickness-twist", Tech. Rpt. No. 13, July 1975.

2. H. G. deLorenzi and H. F. Tiersten, "On the introduction of the electromagnetic field with heat conducting deformable semiconductors," Journal of Mathematical Physics [illegible], 893-897 (1975).

3. H. F. Tiersten, "Analysis of intermodulation in rotated Y-cut quartz thickness-shear resonators", Proceedings of the 28th Annual Symposium on Frequency Control (1974), pp. 1-4.

4. H. F. Tiersten, "Analysis of trapped energy resonators operating in overtones of thickness-shear", Proceedings of the 28th Annual Symposium on Frequency Control (1974), pp. 44-48.

5. H. F. Tiersten and J. C. Baumhauer, "Second harmonic generation and parametric excitation of surface waves in elastic and piezoelectric solids", Journal of Applied Physics 45, 4272-87 (1974).

6. H. F. Tiersten and D. Rubin, "On the fundamental antisymmetric mode of the wedge guide", 1974 Ultrasonics Symposium Proceedings, pp. 117-120.

7. H. F. Tiersten, "Nonlinear electroelastic equations cubic in the small field variables," Journal of the Acoustical Society of America 57, 660-6 (1975).

8. H. F. Tiersten, "Analysis of intermodulation in thickness-shear and trapped energy radiators", Journal of the Acoustical Society of America 57, 667-81 (1975).

DR 318-010, University of California at Los Angeles, "Magnetic Alloys and Organic Conductors," P.I. - Dr. Raymond Orbach, N00014-75-C-0245

The physical properties of conducting organic solids will be investigated theoretically by developing new models of charge transfer in quasi-one dimensional narrow band solids. Electron spin resonance will be used to investigate dilute magnetic alloys that have nearly unstable moments and exhibit large negative exchange coupling. Additional work will be undertaken to investigate the effect of the large negative exchange coupling on negative thermopower in dilute magnetic alloys. Additionally, an investigation of fluctuations in organic superconductors near the superconducting transition temperature will be carried out. Progress: The thermoelectric power of a narrow-band Hubbard chain with an arbitrary number of

electrons per site was studied. The calculations were carried out to the lowest order in the transfer integral. It was found that a characteristic electron density (=2/3) existed below which the thermoelectric power is negative at all temperatures. In contrast, for the density larger than 2/3, the thermopower is small and negative only above a characteristic temperature, below which there is a change of sign and slope. The applicability of the results to the charge-transfer salts of tetracyanoquinodimethane (TCNQ) was pointed out.

Recent Publications:

1. D. Davidov, K. Maki, R. Orbach, C. Rettori, and E. P. Chock, "Re-Entrant Critical Field Behavior in $Gd_xTh_{1-x}Ru_2$: Correlation with EPR," Physics Letters 45A, 163 (1973).

2. D. Davidov, C. Rettori, K. Baberschke, E. P. Chock, and R. Orbach, "Correlation Between Electron Spin Resonance and Superconductivity in $Gd_xB_{1-x}Ru_2$(B=Th, Ce, La)," Physics Letters 45A, 161 (1973).

3. N. L. H. Li and R. Orbach, "Superexchange," A.I.P. Conf. Proc. 10, 1238 (1973).

4. P. Pincus, "Charge Transfer Molecular Solids," Selected Topics in Physics, Astrophysics, and Astronomy, p. 138 (1973).

5. P. Pincus, P. Chaikin, and C. F. Coll, "Correlated Pairs in the Attractive Hubbard Model," Solid State Communications 12, 1265 (1973).

6. C. Rettori and D. Davidov, "Comment on the Hyperfine Constant of Rare-Earth Ions in Dilute Alloys: Th: Fr," Physical Review B 10, 4033 (1974).

7. C. F. Coll and G. Beni, "The Effect of Polarons on the Conductivity of the Narrow-Band Hubbard Chain," Solid State Communications 15, 997 (1974).

8. D. J. Scalapino, Y. Imry, and P. Pincus, "Generalized Ginzberg-Landau Theory of Pseudo-One-Dimensional Systems," Physical Review B 11, 2042 (1975).

9. J-P. Gallinar, "Thermodynamics of an Extended Hubbard-Model Chain. II. Strong-Coupling Limit," Physical Review B 11, 4421 (1975).

10. T. Tonegawa, H. Shiba, and P. Pincus, "Thermodynamics of the Impure Classical Heisenberg Chain," Physical Review B 11, 4683 (1975).

11. P. M. Chaikin, P. Pincus, and G. Beni, "Peierls' Transitions in Alternate Lattices," Journal of Physics C: Solid State Physics 8, L65 (1975).

12. P. Pincus, "Basic Principles and Concepts in the Physics of Low Dimensional Cooperative Systems," in Low-Dimensional Cooperative Phenomena, J. T. Keller, Ed., (Plenum, New York, 1974) pp. 1-21.

13. C. Rettori, D. Davidov, and H. M. Kim, "Crystalline-Field Effects in the EPR of Er in Various Cubic Metals," Physical Review B 8, 5335 (1973).

14. R. Orbach, "Electron Spin Resonance in Superconductors," Physics Letters 47A, 281 (1974).

15. R. Orbach, "Energy Transfer and Anderson Localization," Physics Letters 48A, 417 (1974).

16. R. Orbach, M. Peter, and D. Shaltiel, "The Magnetic Resonance of Dilute Magnetic Alloys," Archives des Sciences 27, 141 (1974).

17. G. Beni and P. Pincus, "Thermodynamics of an Extended Hubbard Chain. I: Atomic Limit for the Half-Filled Band," Physical Review B 9, 2963 (1974).

18. G. Beni, P. Pincus, and J. Kanomori, "Low Temperature Properties of the One-Dimensional Polaron Band. I. Extreme Band-Narrowing Regime," Physical Review B 10, 1896 (1974).

19. U. Bernstein and P. Pincus, "Thermodynamic Properties of the Dimerized Half-Filled-Band Hubbard Chain," Physical Review B 10, 3626 (1974).

20. G. B. Arnold, "Upper Critical Field and Critical Temperature for Superconducting Alloys Described by the Anderson Model," Physical Review B 10, 105 (1974).

21. S. E. Barnes, "Fine-Structure Splitting of a Localized Moment in a Metal: A Diagrammatic Analysis," Physical Review B 9, 4789 (1974).

22. G. Beni, "Peierls Transition in a Quasi-One Dimensional System," Solid State Communications 14, 269 (1974).

23. C. F. Coll, "Excitation Spectrum of the One-Dimensional Hubbard Model," Physical Review B 9, 2150 (1974).

24. O. Entin-Wohlman, G. Deutscher, and R. Orbach, "Anomalous Spin-Flip Lifetime Near the Heisenberg-Ferromagnet Critical Point," Physical Review B 11, 219 (1975).

25. G. Beni and C. F. Coll, "Thermoelectric Power in Half-Filled Bands," Physical Review B 11, 573 (1975).

26. J-M. Moret, R. Orbach, M. Peter, [illegible]
W. Zingg, R. A. B. Devine, and P. B. Zimmermann, "[illegible]
Relaxation Narrowing of the Fine Structure [illegible]
of Pd," Physical Review, B 11, 2003 (1975).

27. F. Fryne, "Magnetic Field Dependence [illegible]
in Antiferromagnets," Physical Review B 7, [illegible]

28. C. Rettori, H. M. Kim, E. P. Chock, and P. Pincus, "[illegible]
Behavior of Paramagnetic Ions and Conduction Electrons in [illegible]
metallic Compounds: $Gd_xLu_{1-x}Al_2$," Physical Review B 10, [illegible]

29. G. Beni, "Thermoelectric Power of the Narrow-Band Tight-Binding
Chain at Arbitrary Electron Density: Atomic Limit," Physical Review
B 10, 2186 (1974).

NR 318-014, Rockwell Science Center, "[illegible]
PbSnTe," P.I. - Dr. John Cape, [illegible]

This program will study conventional Raman characteristics of
grown epitaxial films in vacuo, study the spectra of the laser
induced scattering from oxide growth on the epi-film and correlate
with ESCA data, and will study the spectra after evaporation of a
thin film of Pb or other metal. Progress: Raman studies to date
have indicated that Te precipitates are formed at the surface of
PbSnTe. Scattering from Te and TeO has been observed. Weak
signals from suitably etched PbSnTe surfaces appear to indicate
the presence of Raman scattering from two of the three phonons
from the LO zone center phonon.

NR 318-017, Naval Weapons Center, "[illegible]
of Solids," P.I. - Dr. Victor Rehn.

This program will utilize the NWC facilities at the Stanford Synchrotron
Radiation Project to study the ultraviolet band structure from
4-25eV, and the deep-lying core states [illegible] excitations in the 25-300eV range. First studies will be made
on the materials GaAs, InP, Si, C, and SiC. The objectives are fundamentally determine the energy, symmetry, [illegible] parameters of interband critical points [illegible] band gap, to seek experimental evidence [illegible] exciton or electron-electron [illegible] fundamental gap, and to examine the [illegible] near their bulk and surface plasmon resonances. Progress: [illegible] emissive total yield measurements were made [illegible]

[illegible]
previous [illegible]
[illegible]
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R. L. White

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mobility [illegible]
of the [illegible]
developed [illegible]
progress was [illegible]
YFeO$_3$ and in antiferromagnetic [illegible]
spectrum in a [illegible]
isoelectronic to [illegible]
bar of YFeO$_3$ was [illegible]
simple exponential [illegible]
found with [illegible]
a c-axis bar is not a [illegible]
the extremely hard [illegible]
a-axis bars have begun.

NR 318-020, Naval Surface Weapons [illegible]
Magnetophonon Effects in [illegible]
Burke

Magnetophonon resonances occur whenever [illegible]
electronic states in a magnetic field [illegible]
with which the electrons interact, or when $w_p = iw_c$, where
the phonon frequency, w_c is the cyclotron frequency, and i is an
integer. The effect is measured as an oscillatory [illegible]
for the semiconductor and, very importantly, [illegible]
involved in the transport properties. [illegible]
studies on the PbTe [illegible]
carrier density, lattice [illegible]
measurements will be extended to [illegible]
semiconducting alloy systems. [illegible]
have been observed between [illegible]
$Sn_{20}Te$ and PbTe. Phonon [illegible]
calculating the magnetic [illegible]
of the magnetoresistance as a function of [illegible]
measuring the heavy carrier effective mass [illegible]
dependence of [illegible]

NR 318-023, The American University, "High Power Magnetostrictive Rare Earth Transition Metal Systems," P.I. - Dr. Earl Callen, N00014-75-C-0736

An experimental and theoretical study will be made of various materials based on the rare earth alloys, intermetallic compounds, polyphase suspensions and sintered mixtures to determine their physical properties that influence the parameters suitable for yielding large magnetostriction while preserving good conductivity and structural properties for transducer application. The materials will be prepared and checked for their magnetic properties by Mossbauer analysis, by strain gauges, by conventional torque and direct movement measurements. Progress: In terbium-iron-yttrium (TbFeY) alloys, at small concentrations of Y, the magnetostriction drops linearly with increasing Y. At a critical concentration, the magnetostriction drops to zero. It has been shown in terbium-iron-cobalt (TbFeCo) that the rhombohedral deviates strongly in a nonlinear fashion as the concentration of Fe or Co is varied. The underlying mechanism for this change is just the dependence of the Curie temperature on the alloy concentration. The magnetostriction comes almost exclusively from the Tb sublattice, which dominates the magnetostriction of the transition metal ions.

Recent Publications:

1. A. E. Clark, J. R. Cullen, and E. Callen, "Rhombohedral Magnetostrictive and Magnetic Materials, Distortion of Highly Tb Alloys", Proc. of Conf. on Magnetism and Magnetic Materials, 1975.

2. R. Abbundi, R. Segnan, J. J. Rhyne, and D. Sweger, "Hyperfine Fields in the Absence of Magnetic Order in Dy_xSc Alloys" Proc. Conf. on Magnetism and Magnetic Materials, 1975.

NR 318-024, General Electric Corporate Research and Development Center," Improved Permanent Magnet Materials," P.I. - Dr. J. J. Becker, N00014-74-C-0271

The coercive force in high-anisotropy materials will be investigated in order to supply a basis for the development of permanent magnet materials surpassing the best in existence today, all of which are now based on $CoSm_5$. Present techniques are sensitive enough to permit the measurement of magnetization and hysteresis behavior of single microsample particles in great detail. Further information on the nature of the defects responsible for nucleation events in single particles will be obtained by analysis of magnetization behavior and its dependence on various physical parameters, especially temperature. Progress: Very tiny samples from bulk

sintered Co5Sm magnets measured [illegible] how many magnetization phenomena previously seen only in single particles prepared from cast material. These phenomena include magnetization discontinuities, a quantized dependence of nucleating fields on magnetizing fields, an angular $1/\cos\theta$ trapped-wall dependence, and on occasion a completely rectangular hysteresis loop. Thus for the first time a strong link has been established between earlier reversal mechanism studies and the behavior of bulk Co5Sm magnets, the same defect-nucleated reversal behavior being observed in both.

Recent Publications:

1. J. J. Becker, "Properties of Microsamples of Sintered Cobalt-Samarium Magnets," presented at 20th Annual Conference on Magnetism and Magnetic Materials, San Francisco, AIP Conference Proceedings 24, 676 (1975).

2. J. J. Becker, "Origin of Coercivity in Cobalt-Rare-Earth Particles and Sintered Magnets," University of Dayton Symposium on Crystal Anisotropy and Coercivity of Rare-Earth-Transition-Metal Alloys, Dayton, Ohio, Oct. 17, 1974.

NR 318-027, Massachusetts Institute of Technology, "Magnetic Semiconductors, Detectors, and Electronic Devices," P.I. - Dr. George Pratt, N00014-75-C-0785

Use is made of new models of many electron systems in magnetic solids in order to determine their points of transition from metal to insulator and conditions of spontaneous magnetization. Calculations of energy levels associated with deep traps, defects, and impurities are calculated by means of cluster techniques of energy band theory. The magnetic after-effect will continue to be investigated as a sensitive detection scheme. Progress: The electronic energy levels associated with vacancies and interstitials in PbTe have been calculated using the Johnson-Slater cluster method with a Pb_4Te_4 cluster. This is a SCF relativistic calculation and the results are similar to those reported earlier. Agreement with the previous Parada-Pratt first principles calculation using conventional band theory is also good.

Recent Publications:

G. W. Pratt, "Production of Quasistatic High Magnetic Fields by Switching Low Voltage d.c. Generators", IEEE Trans. on Magnetics, MAG-10, 201 (1974).

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[illegible] heavily
[illegible]-like edges
[illegible] compounds have been
[illegible] from the
[illegible] times below
[illegible] discrepancy is
[illegible] investigation.

[illegible] Insulating Solids,"

[illegible] to formulate structural
[illegible] measurements of photo-
[illegible] silicon-dioxide films will be carried
[illegible] to determine the
[illegible] photon energy and
[illegible] the joint ground
[illegible] these data, the inhomogeneous
[illegible] can be extracted. Other
[illegible] dependence of trapped
[illegible] doped thermal silicon dioxide
[illegible] The [illegible] density of electron
[illegible] the [illegible] photodepopulation response has been
[illegible] the proper procedure for determination of defect energy
[illegible] insulators using the photodepopulation technique was
[illegible] by this method. Trap depopulation kinetics in thermal
[illegible] films were examined. It is proposed that hot electrons
[illegible] the silicon-dioxide by ultraviolet excitation at the
[illegible] insulator interface are involved in inverse Auger
[illegible] electrons [illegible] in traps in the silicon-dioxide.

[illegible] Spectroscopy in Thin
[illegible] and Circuit Current",

[illegible] Emission
[illegible]", Physical Review

NR 318-039, North Texas State University, "Investigation of Optical Biasing on the Quantum Transport Properties of Semiconductors," P.I. - Dr. David Seiler, N00014-76-C-0319

The investigator will study the quantum transport of electrons and holes generated by optical irradiation in the presence of high electric and magnetic fields. During this study, new tools will be developed and utilized to provide information on determination of the non-equilibrium electron temperature and the effect of laser irradiation upon this temperature, to determine the transient effects of the Shubnikov-de Haas and magnetophonon resonance effects in pulsed electric fields and the corresponding energy relaxation times, and to study the properties of the non-equilibrium carriers through spin-splitting of the Shubnikov-de Haas effect. Progress: New

NR 318-040, Stevens Institute of Technology, "Research on Chalcopyrite Semiconductors," P.I. - Dr. George Wright, N00014-76-C-0384

Theoretical calculations of the electron energy bands will concentrate on the differing influence of these effects: the change in the chemical potential of the A-B cation sublattices in perturbation from III-V or II-VI lattices, the effect of the c/a distortion, and the effect of the anion distortion. This study will utilize a blend of symmetry, pseudopotential, deformation potential, and k-P techniques. Experiments will utilize piezo-spectroscopy to ascertain deformation potentials and optical pumping luminescence measurements to ascertain g-factors. Progress: New

NR 318-041, Emory University, "Far Infrared Optical and Magnetooptical Studies of Semiconductors," P.I. - Dr. Sidney Perkowitz, N00014-76-C-0429

Far infrared optical and magnetooptical reflection and transmission measurements will be made in III-V, II-VI, and IV-VI semiconductors and their alloys with particular emphasis placed upon the III-V ternary solid solutions. These data will be utilized to investigate dielectric behavior, coupled phonon-plasmon modes, and multi-carrier properties of the materials. The role of multiple coupled oscillators on the dielectric behavior will be investigated. Polaron coupling and the role of plasma interactions in narrow-gap materials will be investigated. Progress: New

NR 318-042, IBM San Jose Research Laboratory, "Electronic Properties of Anisotropic Organic Solids," P.I. - Dr. P. L. Gruner, N00014-76-C-

The contractor will investigate the following: (1) synthesis, purification, and film and crystal growth of derivatives of polysulphur nitride involving intercalation, substitution, and attachment of side groups, (2) measurement of the conductivity, thermopower, and specific heat of these crystals as a function of temperature; and (3) interpret the above experiments using phenomena oriented models to provide insight into molecular and solid state origins of electronic structure, metal-insulator transitions, densities of states, bandwidths, electronic effective masses, anisotropies and electron-phonon interactions. Progress: New

NR 318-044, Western Michigan University, "Magneto-transport Studies in Semiconductors," P.I. - Dr. Vijay Arora, N00014-76-C-

Calculations will be carried out on magnetotransport effects in semiconductors in the presence of electric fields and thermal gradients. A quantum mechanical approach based upon the solution of Liouville's equation for the density matrix will be utilized. Results will be extended to the cases of nonparabolic bands, inelastic acoustic scattering, many valleyed band structure, and the effects of high electric fields. Progress: New

RR 011-11-01, SUPERCONDUCTIVITY, (F. A. Fielsack, 202 692-4018)

NR 319-054, National Bureau of Standards, Gaithersburg, "Detection of Electromagnetic Radiation by Arrays of Josephson Junctions," P.I. - T. F. Finnegan, NACMP-76-76.

The electrodynamic properties of small arrays of interacting Josephson tunnel junctions are being investigated. Both radiation emission and microwave induced response characteristics are being studied. Junctions are being developed using high transition temperature, large energy gap materials. Progress: The most significant new results achieved with large area Pb-Pb oxide-Pb tunnel Josephson junctions were: (1) the successful injection-locking (with an external 4 GHz microwave source) on small arrays, and (2) the first observation of coherent emission from a radiating three junction array, coupled to a microwave stripline. Radiation from this array was detected at frequencies near 4, 8 and 12 GHz.

Recent Publications:

1. T. F. Finnegan, J. Toots and J. Wilson, "Frequency-Pulling and Coherent-Locking in Thin Film Josephson Oscillators," Proceedings of LT-14, p. 184, (North-Holland Publishing Co., (1975)).

NR 319-055, University of California, Berkeley, "Microwave and Far Infrared Superconducting Detectors for Surveillance Systems," P.I. - P. Richards, N00014-69-A-0200-1056.

The properties of high frequency, wide bandwidth low noise parametric amplifiers using Josephson junctions as nonlinear elements are being investigated. Progress: Experiments at 26 GHz have shown that the noise and the conversion efficiency of mixers containing Pb junctions agree with theoretically determined values. Using a 26 GHz parametric amplifier containing a Josephson junction, significant parametric gain was observed. This is the highest frequency at which gain has been observed.

Recent Publications:

1. "Noise in Josephson Effect mm-Wave Mixers," J. Classen, T. Taur and P. Richards, Proceeding of 1974 Applied Superconductivity Conference, Oakbrook, Ill., 1974.

2. "Josephson Junctions as Heterodyne Detectors," T. Taur, J. Classen and P. Richards, IEEE Transactions on Microwave Theory and Techniques, December 1974, Part II.

NR 319-057, Massachusetts Institute of Technology, "Superconducting Electric Machines for Naval Propulsion," P.I. - Dr. J. L. Smith, N00014-67-A-0204-0068.

The contractor is investigating the characteristics of existing superconducting machines for ship propulsion and comparing them with the characteristics of newly conceived machines. Two new machines concepts under investigation are: (1) superconducting machines having a DC superconducting field winding and two normally conducting armature windings, and (2) a high efficiency variable speed ship propulsion system utilizing AC superconducting motor, and superconducting generator. Progress: The steady state testing of an iron and copper prototype of a superconducting dual armature motor was completed. A starting winding was designed and installed on the inner rotor of this motor. A simplified circuit model for this new dual-rotor class of machines has been developed.

Recent Publications:

1. "Multipole Superconducting Electric Motors for Ship Propulsion," by P. Thullen, T. A. Keim and J. V. Minervini, IEEE Trans. on Magnetics, Vol. MAG-11, No. 2, March 1975, pp. 573-5.

NR 319-062, State University of New York, Stony Brook, "Superconducting Broadband Arrays," P.I. - Professor J. E. Lukens, N00014-75-C-0769.

The radiative properties of broadband superconducting arrays in the 1-18 GHz frequency range are being studied. These series connected arrays consist of many thin film microbridges whose properties are precisely controlled by means of electron-beam and ion milling fabrication techniques. The effects of array size and coupling on microwave output power and on the intrinsic array noise are being studied. Progress: A most important result has been the observation of voltage locking between two series connected

superconducting indium microbridges which were in close proximity. Data show the existence of an internal synchronization interaction without need of a cavity or external radiation.

Recent Publications:

1. "Observation of the intrinsic noise of thin-film microbridge Josephson junctions," Appl. Phys. Lett. Vol. 26, 480, 15 Apr 75, S. S. Pei and J. E. Lukens.

2. "Use of Fluxoid Quantization in the Measurement of the Inductance of Single Junctions SQUIDs," with S. S. Pei, J. Appl. Phys. 46, 2257 (1975).

NR 319-072, The Aerospace Corporation, "Josephson Parametric Amplification at Microwave and Millimeter Wavelengths," P.I. - A. Silver, N00014-76-MP-60007.

Parametric amplification properties of superconducting Josephson junctions at microwave frequencies are being studied. Parametric amplification is being studied as a function of critical current, leakage resistance, junction geometry, and frequency, in order to determine the conditions for optimization of gain, bandwidth, noise figure and frequency conversion. Progress: Impedance measurements were made at 9 GHz on niobium superconducting point contact junctions in a broadband waveguide for the purpose of studying junction parameters. Results were inconclusive due to spurious reflections and lack of an absolute reference impedance. Alternate experiments are being attempted. Experiments to study parametric amplification at 90 GHz are underway.

Recent Publications:

1. "Parametric Amplification with Self-Pumped Josephson Junctions," H. Kanter, IEEE Trans on Magnetics, Vol. MAG-11, 789, 1975.

2. "Low Noise Parametric Amplification with a Self-Pumped Josephson Junction," H. Kanter, J. Applied Physics.

NR 319-075, Stanford University, "Superconducting-Cavity Stabilized Oscillator for Ultra High Stability Radio Frequency Source," P.I. - Professor H. A. Schwettman, N00014-67-A-0112-0087.

The electrical, cryogenic, mechanical and environmental parameters which effect the short term frequency stability and the long term drift of superconducting cavity stabilized oscillators (SCSO) are

being studied. The long term frequency drift of the SCSO are being compared to a cesium beam frequency standard and as part of this study the upper limit of the secular drift rate of the fine structure constant is being measured. Progress: Recent efforts have resulted in the following substantial improvements in the SCSO performance characteristics at 8.6 GHz: (1) the spectral density of phase fluctuations have been reduced by two decades, (2) the short-term frequency stability as measured in the time domain has been reduced by a factor of 20 to 5 x 10^{-15} for sampling times between 1 ms to 10 ms and (3) the long-term fractional frequency drift has been reduced by a factor of four to values of $\pm$ 5 x 10^{-14} per day.

Recent Publications:

1. "Superconducting-Cavity Stabilized Oscillators of 6 x 10^{-16} Stability," F. B. Stein and J. P. Turneaure, IEEE Proceedings Letters, July 1975.

NR 319-080, National Bureau of Standards, Boulder, "Microwave and Far Infrared Superconducting Detectors," P.I. - D. McDonald, NAONR-34-75.

The high frequency response to millimeter and submillimeter radiation of superconducting point contact and tunnel type Josephson junctions are being studied. Frequencies of up to 100 THz are being explored. A theoretical study of picosecond pulse generation by Josephson junctions is in progress. Progress: A prototype low power Stirling-cycle refrigerator made of non-magnetic, non-conducting materials has been built and maintained at 1°K for over 1000 hours with no noticeable wear. The microscopic phenomenological theory of the Josephson effect has been reformulated so as to permit calculation of the intrinsic response time of a Josephson tunnel junction when connected to an arbitrary circuit.

Recent Publications:

1. R. E. Harris, "Intrinsic Response Time of a Josephson Tunnel Junction."

2. R. E. Harris, P. C. Dynes and D. M. Ginsberg, "Strong-Coupling Corrections to the Theory of the Quasiparticle Current of a Superconducting Tunnel Junction."

3. D. M. Ginsberg, R. E. Harris, and P. C. Dynes, "Strong-Coupling Corrections to the Low-Frequency Electrical Conductivity of Superconductors and Superconducting Junctions."

NR 319-081, California Institute of Technology, Pasadena, "Detection of Electromagnetic Radiation by Arrays of Superconducting Junctions." P.I. - J. Mercereau, N00014-75-C-0911.

The coupling between individual elements of an array of superconducting junctions is being examined both theoretically and experimentally. Impedance, noise, emission power, frequency response and sensitivity are being studied. Progress: The oscillation of individual elements in a superconducting series array of proximity coupled Josephson junctions have been found to lock together into a single synchronous mode when the spacing between junctions is made sufficiently small (e.g. less than two microns in arrays of Nb-Ta junctions for frequencies up to 1 GHz). This phenomenon occurs spontaneously without the need of either external radiation or a resonant cavity.

Recent Publications:

1. "Noise Measurements in Superconducting Proximity Bridges," S. K. Decker and J. E. Mercereau, Appl. Phys. Lett. 28, 467 (1976).

2. "Stripline Coupling to Josephson Oscillators," T. Hano and J. E. Mercereau, J. Appl. Phys. 26, 4986, (1975).

NR 319-082, University of Pennsylvania, Philadelphia, "Optically Excited Superconducting Devices," P.I. - D. N. Langenberg, N00014-75-C-0925.

The dc I-V characteristics of the optically-induced weak links are being studied in several superconducting materials. The dependence of the critical current on temperature, light intensity and magnetic field are being investigated. The response of these optically induced weak links to microwave radiation is also being studied. Progress: Using optical excitation to produce an excess of quasiparticles (i.e. non-paired electrons) in thin-film superconducting microbridges has to date proved inconclusive. As an alternate technique, 1 um x 2 um tunnel junction evaporated on a long tin microbridge was used. Quasiparticles were injected through the tunnel barrier. These experiments were successful in demonstrating the feasibility of an electrically tunable superconducting Josephson weak link using the method of localized injection of excess quasiparticles.

Recent Publications:

1. D. N. Langenberg, "Nonequilibrium Phenomena in Superconductivity," Low Temperature Physics - LT14 Vol. 5, (North-Holland/American Elsevier, Amsterdam and New York, 1975), p. [illegible].

319-094, Massachusetts Institute of Technology, "Synthesis of High Transition Temperature A15 Superconducting by Means of Ion Implantation," P.I. - Dr. Robert M. Rose, N00014-76-C-0297.

Substrates of Nb3Al will be prepared, characterized and implanted with Si ions at various dosages and energies. Measurements of transition temperature and other superconducting properties will be made as a function of implantation temperature and initial specimen preparation. Progress: New.

Recent Publications:

None

NR 319-095, University of Maryland, "Noise and Relaxation Phenomena in Solids at Low Temperatures," P.I. - Dr. Joseph Weber, N00014-76-C-0496

The relaxation time associated with the noise from metal and dielectric crystals at low temperatures will be investigated. The noise and Q of a niobium cylinder at low temperature will be studied. Progress: New.

Recent Publications:

None

NR 319-096, Cornell University, "Superconducting Detectors," P.I. - P. Buhrman, N00014-76-C-0526.

The electrodynamic properties and intrinsic noise of superconducting quantum magnetometers biased at rf frequencies above 100 MHz will be determined employing both computer analysis and experimentation. Using superconducting thin film indium weak links and variable thickness niobium bridges as microwave detectors, a detailed study of heating effects will be made. Progress: New.

Recent Publications:

None

NR 319-097, Westinghouse Electric Corporation, Pittsburgh, "Biasing of Microwave Emitting Josephson Junction Arrays," P.I. - M. Janecko, N00014-76-C-0600.

The effects of critical circuit parameters on interconnected Josephson junction circuits will be analytically studied. Thin film junctions to be investigated include the microbridge and proximity types. The emitted radiation from these junctions at X-band frequencies will be experimentally investigated. Signal to noise ratios, power outputs, frequency line width and frequency range of operation are among the parameters to be measured. Progress: New.

Recent Publications:

None

NR 319-098, University of California, Santa Barbara, "Transport Properties of Nonequilibrium Superconducting Materials," P.I. - D. J. Scalapino, N00014-76-C-0525.

The processes by which various nonequilibrium instabilities cause breakdown in superconductors will be studied. For small perturbations from the equilibrium state, the quasiparticle and phonon deviations will be compared for a variety of excitation mechanisms. Changes in energy gap, transition temperature and quasiparticle relaxation rates will be determined. Progress: New.

Recent Publications:

None

319-1000, University of California, Berkeley, "[illegible] Electromagnetic Radiation by Semiconductor-Barrier [illegible] Junctions," P.I. - Professor T. Van Duzer, [illegible].

The current-voltage characteristics of superconductor-semiconductor-superconductor sandwich-type tunnel junctions containing silicon barriers of varying thicknesses and doping profiles will be studied. An improved circuit model of the semiconductor barrier will be developed, using three series-connected shunt RC circuits to represent the quasiparticle and displacement currents. Progress: New.

Recent Publications:

None

NR 319-104, Science Applications, Inc., La Jolla, California, "Properties of Nonequilibrium Superconductors," P.I. - L. Burlin, N00014-76-C-0740.

The dynamic processes by which the phases of two weakly coupled superconductors describing individual electron pairs can lock to form a single-phase state for bulk superconductors and for weakly linked systems will be examined in detail. Superconducting array systems will theoretically be studied with the intent of determining the conditions necessary for mode locking as well as the structure of the self-generated radiation field and the noise characteristics of the system. Progress: New.

Recent Publications:

None

NR 319-104, Catholic University of America, "Time Dependent Superconducting Device Characteristics," P.I. - F. A. Peters, N00014-76-C-

The signal strength and dimensional and frequency limitations of Josephson junction arrays and SQUIDs will be studied as a function of inelastic electron-phonon collision time and quasiparticle diffusion distance. Also the extension of quasiparticle diffusion theory into the rf region will be experimentally tested. Progress: New.

Recent Publications:

None

NR 319-105, Stanford University, "Superconducting Magnetometer," P.I. - R. L. Gifford, N00014-76-C-

Two noise sources, flux noise and voltage noise, will be experimentally measured in order to provide a complete representation of SQUID magnetometer noise. The noise in a 20-30 MHz biased SQUID system will be characterized as a function of frequency, down to input frequencies of 20 MHz. Progress: New.

Recent Publications:

None

[illegible]

[illegible]

This program will attempt to develop an analytic physical technique to solve the problem of diffraction and scatter of electromagnetic waves by a dielectric wedge to enable calculation of the radiation properties of dielectric antenna arrays or of antennas incorporating dielectric supports, as well as the radar reflection and EMP pulse response from dielectric objects. The approach is to expand the fields as an integral of plane waves with field matching at the dielectric surface and develop a pair of coupled functional equations for the spectral density functions. A solution is obtained by matching the singularities in the functional equations, giving a family of poles and branch cuts. The integral equations will be solved using well known techniques such as steepest descent to extract the leading terms of specular reflection, diffracted fields, shadow boundary field, and lateral waves, thus giving both a numerical solution and physical interpretation of the scattering process. Progress: New

Recent Publications:

None

[illegible]

The objective of this study is to perform a theoretical and experimental analysis of propagation on single and coupled microscope transmission lines on an anisotropic substrate such as boron nitride, leading to the design of a 10 dB directional coupler. A theoretical analysis of propagation in single and coupled microstrip transmission lines on a substrate with anisotropic dielectric constant such as boron nitride will be performed using techniques such as the method of moments, and will include analysis of the dispersion relations, line impedance, and losses. An optimum theoretical design for a broadband 10dB directional coupler will be fabricated, and experimental measurements performed to confirm the theoretical analysis. Progress: New.

Recent Publications:

None

NR [illegible], University of Illinois, "Phase Velocity [illegible] of Electromagnetic Waveguide Structures with Arbitrary Apertures in Cylindrical Structures", P.I.-R. Mittra, [illegible]

This effort will carry out an accurate analysis of the aperture coupling phenomena in the cylindrical structures whose radii are comparable to the wavelength of the incident field. It is proposed to employ accurate and efficient numerical and analytical techniques which have been expressly developed for solving the scattering problems encountered. Progress: A spectral domain interpretation of a high frequency diffraction phenomena has been developed which introduces the concept of a spectral diffraction coefficient, resembling Keller's coefficient. The solution of two-dimensional problems of diffraction of an arbitrary field (with no caustics) by a half-plane was investigated and results obtained for any observation angle including, in particular, the determination of the field at the shadow boundaries. The high frequency scalar diffraction by apertures and semi-infinite cylinders is formulated in a systematic manner and the formulation, which is valid for any observation angle was compared with that of Ufimtsev's results were also obtained for the diffracted field at the caustics.

Recent Publications:

None

NR [illegible], Brown University, Providence, R.I., "Peripherally or Edge-Guided Mode in Planar Ferrite Loaded Waveguiding Structures", P.I.-D.M. Bolle, N00014-75-C-0750.

The purpose of this program is to develop the theory of edge guided mode propagation in ferrite loaded waveguides, which will lead to optimum design of microstrip devices such as isolators, phase shifters, circulators and distributed unidirectional microwave amplifiers. Prototype devices utilizing the edge guided mode have been built and are characterized by extremely wide band performance which may be useful for high data rate or spread spectrum communications, or for frequency hopping or high resolution radars, however a basic understanding of this mode

is lacking. The propagation characteristics of the lowest order edge guided modes will be determined for canonical structures of increasing complexity using integral equation and mode matching techniques. Progress: Numerical solutions of the dispersion relations for surface modes on dielectric-ferrite interfaces have been developed. Comparison with the experimental results for the edge guided mode shows similar characteristics. Computer programs were developed for the surface mode which will become an integral part of the more complex programs required to analyze the edge guided mode.

Recent Publications:

None

NR 371-088, University of Colorado, Boulder, Colorado, "Electromagnetic Susceptibility Study of Metallic Enclosures and Electronic Circuits", P.I.-D.C. Chang, N00014-76-C-0318.

This program will investigate, theoretically, the electromagnetic penetration into apertured cylindrical enclosures of circular cross-section. Two types of plane wave penetration scheme will be considered, one with the wave incident broadside to the cylinder, and the other with the wave normally incident upon the end of the enclosure. In addition, a theoretical study will be made of the conditions for the existence of low-attenuation, substrate-attached modes in electronic circuits and transmission structures. The excitation and propagation characteristics of such modes will also be investigated. Progress: New.

Recent Publications:

None

NR 371-089, University of California, Los Angeles, Cal., "Propagation Characteristics of Arbitrarily-Shaped Dielectric Waveguides", P.I.-C.W. Yeh, N00014-76-C-0321.

Finite element techniques will be used to obtain the propagation characteristics of electromagnetic waves along dielectric guiding structures whose cores maybe of arbitrary cross-sectional shape and whose material media maybe inhomogeneous in more than one transverse direction. The proposed methodology will be applied to several important problems dealing with practical optical filter or integrated optical waveguides whose cross-sectional index of refraction distribution maybe quite arbitrary. Progress: An efficient method of computing

the dispersion characteristics and Poynting flux distribution of radially stratified fibers using only 4 x 4 matrix operations has been developed.

Recent Publications:

None

NR 371-147, Polytechnic Institute of New York, Brooklyn, N. Y., "Basic Wave Propagation through Turbulent Ionized Media", P.I.-N. Marcuvitz, N00014-76-C-0176.

Propagation through non-linear and/or turbulent media is being investigated. The general techniques being developed treat the wavepackets as quasi-particles, and treats the propagation through non-linear/turbulent media using kinetic equations. Progress: The areas investigated include electron beam interaction with a background plasma with generation of electron-acoustic waves, coherent wave propagation in a non-linear medium where dielectric constant is a function of the mean square electric field intensity, wave-wave interactions excited by high power EM waves, wave-matter interactions, and microwave scattering from turbulent plasma.

Recent Publications:

1. D. Attwood, "Microwave Scattering from an Overdense Turbulent Plasma," Physics of Fluids, Vol. 17, No. 6, June 1974.

2. D. Attwood, "Suppression of Ionization Waves by Hydro-dynamic Turbulence," Physics of Fluids, Vol. 17, No. 6, June 1974.

3. N. Marcuvitz, "On the Theory of Plasma Turbulence," Journal of Mathematical Physics, Vol. 15, No. 6, June 1974.

NR 371-108, The Ohio State University Research Foundation, Columbus, Ohio, "Fundamental Investigation of a Hybrid Technique for General Electromagnetic Scatterers and Antennas", P.I.-G.A. Thiele, N00014-76-C-0573.

A hybrid technique of determining antenna impedance and radiation pattern will be developed by unifying the method of moments and geometric theory of diffraction. The method of moments technique for calculating the impedance matrix will be extended by separate

calculation of the contribution to the matrix elements from the regimes where the method of moments and geometric theory of diffraction respectively apply. Progress: New

Recent Publications:

None

NR 371-401, Massachusetts Institute of Technology, Cambridge, Mass., "Ultra-Low Frequency Radio Signals", F.I.-T.F. Madden, N00014-76-C-0067

The purpose of this program is to investigate naturally occurring ULF radiation known as micropulsations. Micropulsations near the Schumann Resonance (about 8 Hz) can be used to detect large ionospheric disturbances due to polar cap absorption (PCA), sudden ionospheric disturbances (SID) events, and nuclear blast. Since the resonances are excited by lightning, they can be used to track thunderstorm activity. At lower frequency, the effective surface impedance can be measured by taking the ratio of horizontal E field to H field. Since the skin depth increases with decreasing frequency, the effective earth conductivity profile can be determined. Geothermal areas can be determined in this manner since the conductivity is temperature dependent. The earth conductivity profile is an important factor in ELF antenna siting since the efficiency increases with decreasing earth conductivity. Progress: A study of electrical conductivity structures in New England using dc lines and low frequency magneto-telluric has been completed. A very thorough treatment of the error analysis and the special problems of combining magneto-telluric data collected from widely dispersed areas were considered. The electric fields in Vermont were strongly affected by the continent-ocean edge effects, but strong edge effects were also found at the western end of the array.

Recent Publications:

1. F.W. Kasameyer and T. F. Madden, "Low Frequency Magnetotelluric Survey of New England", Tech. Report, September 1976.

NR 371-395, Syracuse University, Syracuse, N.Y., "Synthesis of Reactively Loaded Antenna Systems", P.I.-P.P. Barrichelo, N00014-76-C-0245.

The use of reactively loaded antenna arrays to form and steer directive beams will be investigated. The effect of the proper choice of the reactive loads in influencing the frequency bandwidth will be investigated. Characteristic modes of the antenna structure are used to synthesize a desired pattern, or to optimize a given parameter, and then to resonate the current by reactive loading of elements. Progress: Good results have been obtained on small reactively-loaded linear and circular arrays for forming directive beams and scanning them by varying the reactive loads. Such arrays have the following advantages over conventional phased-array antennas: (1) Only one element is fed by the transmitter, hence, matching the array to the transmitter is accomplished by a single one-port matching network. (2) No transmission lines are connected to the remaining elements, their excitation being obtained from the electromagnetic interaction. (3) Control of the directive beam is obtained by reactances which can be varied by electronic means. (4) All mutual interactions between elements are accounted for in the theory, and in fact are necessary for proper control of the array. Techniques for mazimixing endfire gain of a linear array have been developed. Mathematical techniques for the analysis of a non-linearly loaded multiport antenna structure was developed, including the effect of imperfect ground.

Recent Publications:

1. R. F. Harrington and J. R. Mantz, "Reactively Loaded Directive Antennas", Technical Report 74-6, September 1974.

2. Y. Chang and R. F. Harrington, "A Surface Formulation for Characteristic Modes of Material Bodies", Technical Report 74-7, October 1974.

3. H. K. Schuman and R. F. Harrington, "A Low Frequency Expansion for Characteristic Modes of Conducting Bodies", Technical Report 75-3, August 1975.

4. R. F. Harrington, R. F. Wallenburg and A. H. Harvey, "Design of Reactively Controlled Antenna Arrays", Technical Report 75-4, September 1975.

5. J. Luzwick and R. F. Harrington, "A Comparison of Optimization Techniques as Applied to Gain Optimization of a Reactively Loaded Linear Array", Technical Report 76-1, Feb 1976

6. T. K. Sarkar, L. L. Weiner, and R. F. Harrington, "Analysis of Nonlinearly Loaded N-Port Antenna Structures", Technical Report 76-2, Apr 1976.

RR 021-01-02, SPACE RADIATION ENVIRONMENT (Dr. H. W. Mullaney, [illegible]-692-4014/15/16)

NR 323-001, University of Iowa, Iowa City, Iowa, "Communication: Polar Radiations in Near Space, Interactions with the Magnetosphere & Ionosphere, & Effects on Naval Communications," P.I.-Professor J. A. Van Allen, N00014-76-C-0016.

Emphasis is on: corpuscular radiations trapped or transiently present in the earth's magnetic field, and solar, interplanetary and terrestrial phenomena associated with these radiation (e.g. solar flares, aurorae, geomagnetic storms, heating of the atmosphere and ionospheric effects of particle precipitation); energetic solar electrons; solar x-rays; very low frequency (VLF) radio phenomena in the magnetosphere; radio frequency emissions from the sun and flare activity; and interactions of the solar wind with the magnetosphere. Progress: HAWKEYE I was launched and all scientific instruments are operating perfectly. Data is being taken from the energetic particle, electric and magnetic field experiments and reduced to a preliminary master science data tape in real time. The entire data acquisition and reduction system is setting a new standard for the efficient and rapid handling of data from a satellite. Preliminary papers on the scientific results of these experiments in the polar cusp region of the magnetosphere have been reported.

Recent Publications:

1. E. T. Sarris and J. A. Van Allen, "Effects of Interplanetary Shock Waves on Energetic Charged Particles", J. Geophys. Res., 79, 4157-4173, 1974.

[illegible], Stanford University, Stanford, Calif., "[illegible] Environment [illegible] Disturbances", [illegible]-Dr. J. M. Wilcox, [illegible]

[illegible] solar telescope [illegible] the [illegible] magnetic field [illegible] geomagnetic conditions and disturbances, the prevailing conditions in the solar wind and the interaction between the earth's magnetic field and the solar magnetic fields as they vary in the vicinity of the earth. [illegible] the center of the visible disc will be observed [illegible] magnetic waves that rise upward into the corona, steepen into shocks and deposit energy into the solar wind. In progress: Final alignment of a solar telescope [illegible] the mean solar magnetic field has been completed. The analysis of the relation between the polarity of the interplanetary magnetic field and polar geomagnetism has introduced a new and previously unknown polar current system and requires a major revision of the accepted theory of polar cap geomagnetic variations. A new [illegible] of the spiral magnetic field has been [illegible] the discovery of a polarity and sunspot cycle variation in that during some parts of the cycle the spiral angle of interplanetary field [illegible] degrees more or less than the predicted 45° degrees.

Recent Publications:

1. J. M. Wilcox, "Solar Activity and the Weather", [illegible], [illegible].

2. [illegible], [illegible], "[illegible] Polar Cap Magnetic Variations", Journal of Geophysical Research [illegible], [illegible], [illegible].

3. [illegible], J. M. Wilcox, "[illegible] Interplanetary Magnetic Field Polarity and [illegible] Cycle Variation", [illegible], [illegible], [illegible].

4. [illegible], [illegible], "[illegible]", [illegible], [illegible].

5. [illegible], [illegible], "[illegible]", Solar Physics [illegible], [illegible].

K. L. Svalgaard, J. M. Wilcox and T. L. Duvall, "A Model Relating the Polar and the Sector Structured Polar Magnetic Fields", Solar Physics 37, 157-170, 1974.

J. H. H. Scherrer, M. El-Fay, "The Relationship Between the Slowly Varying Component of Solar Radio Emission and Large Scale Interplanetary Magnetic Field Patterns", Solar Physics 45, 361-369, 1975.

NR 373-004, University of California, Berkeley, Cal., "Ionospheric Vector Electric Field Measurements", P.I.-Dr. F. S. Mozer, N00014-75-C-0204.

A vector electric field experiment has been designed and built to be flown on an Air Force satellite S3-3 expected to be launched this year. The launch into a polar orbit with an apogee of 5000 miles will enable vector electric field measurements in a previously unexplored region. This launch is part of DOD STP Flight Two. Progress: Electric field data from satellite observations have revealed an isotropic electric field vector at 600 km in the high latitude regions which is not coincident as had been predicted by theory. The region of this turbulent electric field is in agreement with that of ionospheric plasma turbulence as determined from scintillation of radio stars and measurements of spread F. An additional mode, not electrostatic, is due to the electric component of an electromagnetic wave giving an observed ordinary or RHF bias. Observations of intense low-frequency electric field fluctuation near the magnetic equator are correlated with spread F at equatorial ground stations suggest ionosphere electric field turbulence is caused by same instability responsible in the high latitude case.

Recent Publications:

1. F. S. Mozer, M. C. Kelley, "A Review of the Recent Results of In-site Ionospheric Irregularity Measurements and Their Relation to Electrostatic Instabilities", Proc. of IEEE, 1-9, 1975.

2. M. C. Kelley, C. W. Carlson, F. S. Mozer, "Application of electric field and Fast Langmuir Probe for the In-situ Observation of Electrostatic Waves and Irregularities", Proc. of IEEE, 6-8, 1975.

3. M. F. Ruhnke, M. C. Kelley, "The Temperature Gradient Drift Instability of the Equatorward Edge of the Ionospheric Plasma Trough", J. Geophys. Res., (submitted) 1975.

4. M. C. Kelley, F. T. Tsunoda, F. S. Mozer, "Irregularities and VLF Electromagnetic Waves in and above the Earth's Ionosphere Detected from Plasma Wave Experiments on the 'Injun-5' and 'S3-3' Satellites", J. Geophys. Res., (in press) 1975.

NR [illegible]-006, University of California, Los Angeles, Cal., "Communications: Magnetospheric Substorms", P.I.-Dr. R.L. McPherron, N00014-69-A-0200-4016.

Ground and satellite magnetic field data will be used to infer parameters of models of field aligned currents during the growth phase of a substorm. Studies of substorm magnetic perturbations will continue. This work includes improvements in our mid-latitude magnetic mapping procedures, improvements in the parameterization of substorm growth and expansion phases, and application of these improved procedures to a large set of computer identified substorm expansions. An attempt will be made to determine in what manner partial ring current development precedes major substorm expansions and how frequently a major expansion causes further ring current enhancement during the expansion phase. Progress: Studies of ground and satellite signatures of multiple onset substorms have shown that the near earth plasma sheet thins prior to onset followed by a rapid expansion in response to each onset while in the distant tail the plasma sheet thins following the first onset and expands only after the last of a sequence of onsets.

Recent Publications:

1. Russell, C. T., McPherron, R.L. and Burton, R.K., "On the cause of geomagnetic storms", J. Geophys. Res., 79 (7) 1105, 1974.

2. Olauer, C.E. and McPherron, R.L., "Mapping the local time-universal time development of magnetospheric substorms at mid-latitudes", J. Geophys. Res. 79 (19), 2811, 1974.

3. Olauer, C.E. and McPherron, R.L., "Variability of mid-latitude magnetic parameters used to characterized magnetospheric substorms", J. Geophys. Res. 79 (19), 2898, 1974.

4. Horning, R.L., McPherron, R.L. and Jackson, D.D., "Application of linear inverse theory to a simple current model of the magnetospheric substorm expansion", J. Geophys. Res., 79 (34), 5209, 1974.

5. Saan, M.N., McPherron, R.L. and Russell, C.T, "Substorm and interplanetary magnetic field effects on the geomagnetic tail lobes", J. Geophys. Res., 80 (1), 191, 1975.

6. Rokutun, S., McPherron, R.L. and Russell, C.T., "Triggering of substorm expansion phase by storm sudden commencement", JGR, 56 (10), 217, 1974.

7. Fytte, T., McPherron, R.L. and Rokutun, S., "Ground and satellite measurements during westward moving substorms", JGR, 56, [illegible], 1176, 1974.

8. Caan, M.N., McPherron, R.L. and Russell, C.T., "The magnetic signatures of magnetospheric substorms: Computerized statistical analysis", JGR, 56, [illegible], 1974.

9. West, H.I., Jr., Fytte, T., McPherron, R.L. and Buck, R.M., "The response of the near-earth plasma sheet to multiple minor substorms", JGR, 56, [illegible], 1975.

10. Fytte, T., McPherron, R.L., Hones, E.W. and West, H.I., Jr., "The distinction between substorms and convection-driven near-zone negative bays", JGR, 56, [illegible], 1975.

NSF GA-[illegible], Stanford University, Stanford, Cal., "Experimental and Plasma Radiation", P.I.-Professor R.A. Sturrock, NSF[illegible]-A-[illegible]-[illegible].

Study relating to solar flares and their prediction will continue. Study of flare mechanisms and radiations and magnetic field changes as observed in visible and UV as indicators of preflare conditions. The solar atmosphere will be modeled to include magnetic fields with their energy loss, heat flow, and propagation of hydromagnetic waves. Data from the Mk I coronameter, which views the sun in the H-alpha band will be compared with the theoretical analysis. Progress: An analytical/numerical model of whistler wave-electron beam coupling to predict triggered VLF emission in the earth's magnetosphere has been developed. A model for predicting solar UV emissions has been developed.

Recent Publications:

1. Y. Nakagawa, Dust, E., "The Structure and Release of Magnetic Energy", Flare-Related Magnetic Field Dynamics (Conference [illegible]), High Altitude Observatory, Boulder, Colorado, p. [illegible], [illegible].

2. C.W. Knight, P.A. Sturrock, "Two-Fluid Model of the Solar Corona", Sol. Phys., [illegible], [illegible], 1974.

1. A.H. Bressler, J. M. Zimmet and R.J. White, "Acoustic [illegible] and Attitude Perturbations of Atmospheric Sounding [illegible]", J. de Phys. Res., 72, [illegible].

[illegible], J.L., J. M. Hoge, and J.J. Lynn, "[illegible] by Sphere-[illegible] Model", Defense Science [illegible], [illegible] and Sea Level", J. Acoustic. Soc. Am., [illegible].

[illegible] and R. J. White, "[illegible] [illegible]", J. Fluid Mech., [illegible].

[illegible], Harvard-Smithsonian Center for Astrophysics, Cambridge, Mass., "Coordinated Study of Solar Flares and Their Manifestations", [illegible] Howard, [illegible].

The work will consist of obtaining and reducing data from the solar magnetograph at the Mount Wilson Observatory, which will provide information concerning magnetic and velocity fields on the sun. The results will be analyzed for basic processes in the development and decay of solar active regions and in the solar activity cycle. Full-disk observations as well as fine-scan observations will be made. Specific observing programs will include a study of the magnetic fluxes, lifetimes, and rotation rates of small magnetic features. These are important characteristics of the fundamental magnetic elements on the sun. Data reduction of accumulated material will continue with emphasis on circulation patters of the solar atmosphere and the relation of these patterns with solar activity. Progress: Spherical harmonic analysis of the magnetic fields on the solar surface over recent years has been completed. By this means the large-scale structure of the corona magnetic field will be examined. It is this field that represents the base of the interplanetary magnetic field and determines initial conditions for the solar wind and transmission of particles through interstellar space to the earth.

Recent Publications:

1. Howard, R., "Studies of Solar Magnetic Fields: The Magnetic Fluxes", Solar Physics, 38, 59. 1974.

2. Howard, R., "Studies of Solar Magnetic Fields: The Average Field Strength", Solar Physics, 38, 283 1974.

3. Howard, R., "Studies of Solar Magnetic Fields: The East-West Orientation of Field Lines", Solar Physics, 39, 275 1974.

4. Altschuler, M. D., Trotter, D.E., Newkirk, Jr., G., and Howard, R., 1974, Solar Physics, 39, 3 1974.

NR 323-028, Lockheed Palo Alto Research Lab, Palo Alto, Cal., "Navy Environment: Magneto-Ionospheric Plasma", P.I.-Dr. E.G. Shelley, N00014-75-C-0099.

The experiment is an energetic ion mass spectrometer and a multi-channel electron spectrometer which measures low-energy ions and elections in the range from a fraction of a keV to about 30 keV. The opportunity to use heavy ions as tracers to probe mass and charge-dependent magnetospheric processes will furnish a new technique to study the still unknown mechanisms responsible for the energization and transport of magnetospheric plasma. A measurement with higher sensitivity and better mass resolution will be performed and extended to energy ranges not covered in the previous experiment. The possibility also now exists of performing active experiments in coordination with chemical releases planned by DNA, NASA, and the Max-Planck Institute of Germany. Progress: Construction of instrument is proceeding according to schedule.

Recent Publications:

[illegible]

NR 323-031, Cornell University, Ithaca, New York, "Communications: Electrostatic Waves", P.I.-Dr. M.C. Kelley, N00014-75-C-0780.

A vector electric field measurement has been designed and built to be flown on an Air Force satellite S3-3 expected to be launched this year. The launch into a polar orbit with an apogee of 5000 miles will enable vector electric field measurements in a previously unexplored region. This launch is part of the DoD STP Flight 74-2. Progress: Electric field data from satelite observations has revealed an isotropic electric field vector at 400 km in the high latitude regions which is not coincident as had been previously reported by others. The region of this trubulent electric field is in good agreement with that of ionospheric plasma turbulence as deduced from scintillation of radio stars and measurements of spread F. An additional mode, not electrostatic, is due to the electric component of an electromagnetic wave giving an observed emission of ELF hiss. Observations of intense low-frequencey electric field fluctuation near the magnetic equator are correlated with spread F at equatorial ground stations suggest ionosphere electric field turbulence is caused by same instability responsible in the high latitude case.

Recent Publications:

1. M.E. Hudson, M.C. Kelley, "The Temperature Gradient Drift Instability at the Equatorward Edge of the Ionospheric Plasma Trough", J. Geophys. Res. (in press).

NR 308-082, McDonnell Douglas Astronautics Co., Huntington Beach, Cal., "Communications: Quantitative Global Model of Ionospheric Electron Density", P.I.-W.P. Olson, N00014-75-C-0801.

A quantitative model, global in extent, will be developed to predict ionospheric electron density using monitored data from ground stations and satellite systems such as SOLRAD and ISMT. Solar electromagnetic fluxes, fluxes of charged particles into the ionosphere will be used to input this model. Progress: Work is progressing on schedule.

Recent Publications:

None

NR 308-089, Stanford Electronics Laboratory, Stanford, Cal., "Communications. VLF/ELF Propagation Effects", P.I.-Professor R.A. Helliwell, N00014-67-A-0112-0012.

To study the effects of wave-induced particle precipitation on VLF/ELF propagation in the earth-ionosphere waveguide, available experimental data on whistler-induced perturbations will be used to develop a physical model of the perturbation. From this physical model an electrical model will be derived to explain the observed perturbations (up to 6db) in VLF/ELF signal strength. A model of magnetospheric duct propagation will also be developed. This model will be used to predict the whistler-mode field intensity at a given ground observation point from a given transmitter. Progress: Artificially stimulated VLF emissions (ASE) are triggered in the magnetosphere by whistler mode signals from transmitters. These emissions may be separated into two classes, rising and falling in frequency. Several hundred ASE have been analyzed by Fast Fourier transform. Averages taken over many events indicate that both rising and falling tones show the same initial behavior. The emissions begin at the frequency of the triggering signal rather than at an offset frequency. Both tones initially rise in frequency, falling tones reversing slope at a point 1.5-2.0 Hz above the triggering signal.

Recent Publications:

1. Stiles, G.S. and R.A. Helliwell, "Frequency-time behavior of artificially stimulated VLF emissions", J. Geophys. Res., 80, 608, 1975.

2. G.G. Stiles, "Controlled VLF Experiments", in VLF-ULF Radio Wave Propagation, J.A. Holtet, Ed., D. Reidel Pub. Co., Dordrecht-Holland, 1974), pp. 185-209.

3. Bell, T.F.,"ULF wave generation through particle precipitation induced by VLF transmitters", (to be published in J. Geophys. Res., 1975).

4. Walker, A.D.M., "The theory of whistler propagation", (submitted to Rev. of Geophys. Space Phys., Aug. 1975)

PHYSICAL ELECTRONICS

NR 051-0[illegible]-01, PHYSICAL ELECTRONICS (Dr. David K. Ferry, [illegible])

NR 372-002, IBM T. J. Watson Research Center, "Electronic Structure and Properties of the Oxides of Tetrahedral Semiconductors," P.I. - Dr. Socrates Pantelides, N00014-76-C-

The oxides of the tetrahedral semiconductors (SiO_2, GeO_2, PnO_2 and the ABO_4-type oxides of the AB-type compound semiconductors, e.g., $AlPO_4$, $GaAsO_4$, etc.) are important technological materials used widely in the fabrication of electron devices. Their crystal structures are generally complicated and the overall symmetry is low so that theoretical studies of the properties of these materials have been very limited in scope. In this program, a theoretical investigation of the properties of these materials will be carried out using both conventional and newly-developed techniques, particularly suited to the situation and exploiting complementary aspects of tight-binding pseudopotential methods. This investigation will include the energy bands, x-ray photoemission spectra, optical absorption spectra, x-ray emission and absorption spectra, dielectric functions, effective charges, elastic constants, stability of structures, heats of formation, the electronic structure and dynamics of defects, and surface and interface states. Progress: New

NR 372-003, Brown University, "Experimental and Theoretical Investigation of the Transport Properties of Semiconducting Surface Inversion Layers," P.I. - Dr. Philip Stiles, N00014-76-C-

This program will investigate both experimentally and theoretically, the physics of charge transport in compound semiconducting surfaces. The first experimental approach will be to obtain good insulator-semiconductor interfaces and explore the above phenomena. It is intended to characterize the material, physics, and technological properties. The investigators will ascertain the theoretical role of material parameters, the single particle spectrum, many-body effects, and model interfaces to ascertain what role other parameters play in this charge transport. It is their intention to arrive at a realistic theoretical description of both charge transport and localization in the interface of semiconductors. Progress: New

NR 372-025, University of Colorado, "Heterojunction Contacts for Transferred Electron Devices," P.I. - Dr. Russell Hayes, N00014-75-C-0472

Controlled heterojunction contact barriers will be prepared by growth of quaternary lattice-matched layers of (In, Ga) (As,P) solid solutions on indium phosphide. By varying the constituency of the quaternary compound, it will be possible to vary the heterojunction barrier height continuously, and thus to determine its effect on the performance of transferred electron devices in indium phosphide. Lattice matching is important to minimize defect states at the heterojunction interface. Theoretical analysis will accompany the experiments to provide a sound scientific basis for a rational heterojunction technology. Progress: InGaAsP layers have been grown on InP with composition that are approximately lattice matched to the InP and with a band gap in the 1.35-1.37 eV range. The layers were compensated n-type with a net donor concentration of $1x10^{17}$/cc and an electron mobility of 2250 cm^2/V-sec. Photoluminescence studies indicate a Zn or Cd acceptor is present.

NR 372-026, California Institute of Technology, "Condensation of Injected Electrons and Holes in Semiconductors," P.I. - Dr. Thomas McGill, N00014-75-C-0423

A comprehensive experimental program will study the condensation of the electron-hole gas injected in semiconductor double injection devices at low temperatures. Emphasis will be placed on studying the electrical device double injection process at low temperatures and its interaction with condensate will be developed. Progress: Electrically injected carriers at low temperatures may be found as free electrons and holes, as excitonic pairs, as bound excitons, or as an electron-hole condensed liquid. This latter phase is a high density phase containing about $3x10^{18}/cm^3$ in silicon. Impurities play an important role in determining which state the carriers are in and the time decay of the nonequilibrium distribution. Electric fields have been shown to affect the population dynamics of the various phases.

Recent Publications:

1. V. Marrello, T. F. Lee, R. N. Silver, T. C. McGill, and J. W. Mayer, "Condensation of Injected Electrons and Holes in Germanium," Phy. Rev. Letters 31, No. 9, 593-594 (1973).

2. R. B. Hammond, V. Marrello, R. N. Silver, T. C. McGill, and J. W. Mayer, "Condensation of Injected Electrons and Holes in Silicon," Solid State Comm. 15, 851-853 (1974).

3. V. Marrello, P. B. Hammond, R. N. Silver, T. C. McGill, and J. W. Mayer, "Electron Hole Condensate Radiation from Ge Double Injection Devices Between 1.5° and 4.2°K," Phys. Letters 47A, 3, 237-238 (1974).

NR 372-035, Stanford University, "Control of Impurities in the Epitaxial Growth of High Quality GaAs," P.I. - Dr. David Stevenson, N00014-75-C-0887

The investigators will analyze the thermal-chemical reactions in a controlled growth system to determine the source of impurities, correlate the residual impurity with gas species, and modify the reactions accordingly. Two principal activities are to be undertaken: the development of liquid phase epitaxial growth techniques to control impurities; and the design and construction of a molecular beam-mass analyzer system to sample, at growth temperatures and atmospheric pressure, the gaseous environment involved in the chemical transport reactions during crystal growth. Progress: It has been shown that a major source of impurities in the growth of GaAs epitaxial layers arises from chemical transport reactions involving the protective gas atmosphere, container and crucible materials and growth ingredients. In growth studies, dramatic changes in layer properties occur for different pre-growth annealing conditions. The shallow and deep levels appear to be dependent on impurities that arise from chemical reactions between the growth system components. A model on the attachment at the liquid-solid interface has been developed that predicts that impurities are segregated at the boundaries of clusters of GaAs. Both n- and p-type layers were produced, depending upon the anneal. The design and construction of a molecular beam-mass analyzer is described that is capable of analyzing a gaseous system at high temperature and at atmospheric pressure.

Recent Publications:

B. L. Mattes, Yu-M. Houng, and G. L. Pearson, "Growth and Properties of Semi-Insulating Epitaxial GaAs", J. Vac. Sci. and Technology 12, 869 (1975).

NR 372-055, Princeton University, "Compound Semiconductor Surfaces," P.I. - Dr. Peter Mark, N00014-75-C-0394

This program will carry out research on the microscopic surface and bulk properties of semiconductors that influence the formation of thin film overlayers and surface reaction kinetics. The effects of bulk doping and of surface crystallographic index and structure, surface composition and surface topography will be investigated. Analytical

tools will include low energy electron diffraction, Auger electron spectroscopy, scanning electron microscopy, conductivity modulation, and ellipsometric analysis. Progress: The systematic examination of the surface structure of various compound semiconductors was continued by a LEED examination of CdS surfaces. From a complete LEED symmetry analysis, it has been concluded that the non-polar surfaces terminated with an ideal surface unit mesh and that the final lattice plane spacing is within [illegible] of the ideal termination. This is in agreement with earlier similar work on ZnO, reported on this contract. The polar surfaces, in contrast, always terminate in a non-ideal fashion. They are either reconstructed, faceted, covered or terminated with the incorrect rotational symmetry so that certain patches of the surface were wurtzite-connected and other patches were zincblende-connected. A systematic study of the effect of bonding ionicity on the kinetics of gas-solid interactions at ordered non-polar compound semiconductor surfaces has been begun and the initial results have been published. This work was stimulated by the earlier research which showed that oxygen uptake at ordered surfaces of ZnO and CdS was much slower than that reported in the literature for ordered surfaces of Si. It was also stimulated by the early work of Mead and collaborators who showed that bonding ionicity played a dominant role in Schottky barrier formation.

Recent Publications:

J. [illegible] C. Duke and J. Mark, "LEED Analysis of the Ideal Non-Polar Surfaces of ZnO", J. Vac. Sci. Technol. [illegible], [illegible] (1978).

J. [illegible] C. Duke and J. Mark, "LEED Analysis of the Ideal Non-Polar Surfaces of CdS," J. Vac. Sci. Technol. [illegible], [illegible] (1978).

J. [illegible] Mayer and J. Mark, "[illegible] Metal-Insulator-Metal Structures," [illegible], (1978).

R. Brauer, J. [illegible] and J. Mark, "[illegible] Effects in [illegible]," J. Vac. Sci. Technol. [illegible], [illegible] (1978).

J. Mark and A. [illegible], "[illegible] Surface [illegible] Ionicity," [illegible], (1978).

J. [illegible], [illegible], [illegible] and J. [illegible], "[illegible] Surface [illegible] Ionicity," [illegible], (1978).

NR 372-058, Brown University, "Transport Properties of InGaAs Solid Solutions at High Electric Fields," P.I. - Dr. Maurice Glicksman, N00014-75-C-0565

The investigator will measure the velocity-electric field characteristics of n-type samples of high quality solid solutions of InGaAs. Measurements will be made on material epitaxially grown on GaAs substrates, and having values of composition corresponding to x between 0 and 0.25. Initial studies will focus on the measurement of the characteristics using short pulse and microwave techniques. In later stages, the focus will be on the theoretical analysis of the data to determine the scattering parameters of the material. Progress: Preliminary measurements of InGaAs alloy samples indicate that the threshold field for Gunn effect increases with increasing InAs composition. Apparatus has been assembled for studying the microwave properties of the alloys.

NR 372-[illegible], University of Texas, "The Synthesis of Useful Electronic Structures Using Solid-Solid Phase Reactions Near Surfaces," P.I. - Dr. Roger Walser, N00014-75-C-0916

Solid-solid surface reactions (solid phase epitaxy) may offer an important new method for realizing reasonably complex layered device structures with a minimum of processing complexity. The interfaces in these structures formed by this technique may be quite different than those formed by serial deposition from the vapor phase or growth from a gas-solid interface. The difference in terms of impurities and lattice mismatches at the boundaries may have significant effects on device performance, reliability, life and repeatability of fabrication. The main objective of this study is to develop a specific set of thermodynamic and kinetic requirements for each useful type of electronic structure. This may involve an overall set of rules in terms of heats of formation, kinetic constants, etc., for thin film growth between two elements or compounds. In addition, the constraints implied by considering specific combinations of materials with radically different transport properties in a definite order may well allow us to be more specific in these rules or allow us to re-specify them in terms of substitute but more readily available static thermodynamic constants in place of some kinetic parameters. Specific systems upon which this effort will concentrate are binary and ternary systems with layered structures of the form M_xSi, $M_xSi_yM_z$, MIS, $M_xSi_yM_z$ and M_xM_y, etc., where M refers to a metal and Si to a semiconductor. The latter is of interest because it corresponds to the Si-metal binary systems for which experimental data currently exists and is being expanded by this program. Progress: During the past year, a model for the first phase nucleated in a planar binary reaction couple has been

novel phase admitted for publication. [illegible] experimental indications are that the state of lowest eutectic composition is of first order importance as an initial condition preceding the nucleation of the first crystalline phase. This eutectic phase may be either a supercooled metastable state produced by the initial formation process or else it may indeed be the equilibrium phase for a narrow interfacial region. These have led to the conclusion that the first compound nucleated in planar binary reaction couples is the most stable congruently melting compound adjacent to the lowest temperature eutectic on the bulk equilibrium phase diagram. Preliminary analysis of the initial formation in binary reaction couples suggests that the stability of properly prepared interfaces, and subsequent nucleation phases, is dependent on the as-deposited concentration profile. The investigators propose that the lowest energy state of the interface system is possibly an amorphous binary solid with the lowest eutectic concentration. It is speculated that the stability of this interface is related to its width and new phases are nucleated at temperatures where large concentration [illegible] are generated by the onset of chemical reactions at the interfaces.

NR 372-077, California Institute of Technology, "Solid Phase Epitaxial Growth," P.I. - Dr. Marc Nicolet, N00014-75-C-0913

The broad objective of the program is to investigate the basic processes which control this form of epitaxial growth. It is proposed to study: (1) growth kinetics, (2) the role of the metal layer, (3) incorporation of dopant atoms, and (4) correlation with regrowth of implanted amorphous layers and consideration of other substrates such as Ge or GaAs. A second task will further investigate the metal-silicon interface and dissolution and growth reactions which take place at this interface. Measurements will be made on the velocities of dissolution and/or growth proceeding simultaneously in several crystal directions. A third, new task will investigate the effects of high dose rate and high dose effects on ion implantation on the growth of the epitaxial layers. Progress: During the last year, backscattering spectrometry and scanning electron microscopy (SEM) have been used to study the transport of Si from an amorphous Si layer (< 1 μm) through a Pd-silicide layer onto <100> oriented Si. For a given annealing temperature, two distinct stages of this process have been observed. The initial transient stage starts with island growth of Si and ends with a uniform layer of Si on the substrate. The thickness of the initial transient stage is found to be equal to the thickness of the Pd-silicide layer. The second stage of growth is characterized by a linear time dependence which is 5-10x slower than the transient stage. Auger electron spectroscopy has established that carbon is present in the Pd-Si and the amorphous Si layers, probably arising from the carbon crucible of the evaporation system. These carbon impurities may be related to the variation in growth rate observed between different runs. Nickel silicide gives rise to growth that is qualitatively similar to Pd-Si, but the

transient state is less distinct. Investigations of intentional doping of the grown layers has begun.

Recent Publications:

1. J. C. McCaldin, "Atom movements occurring at solid metal-semiconductor interfaces," Journal Vacuum Science and Technology 11, 990 (1974).

2. H. Muller, W. K. Chu, J. Gyulai, J. W. Mayer, T. W. Sigmon, and T. R. Cass, "Crystal orientation dependence of residual disorder in As-implanted Si," Applied Physics Letters 26, 292 (1975).

3. C. Canali, S. U. Campisan, S. S. Lau, Z. L. Liau, and J. W. Mayer, "Solid-phase epitaxial growth of Si through palladium-silicide layers," Journal of Applied Physics 46, 2831 (1975).

4. J. C. Best and J. O. McCaldin, "Si-Al Interface Shapes Developed during heating of integrated circuits," Journal of Applied Physics 46, 4071 (1975).

NR 372-087, Naval Surface Weapons Center, "High Field Transport in Ternary Alloy Semiconductors," P.I. - Dr. Gary Carver

This program will study the transport properties of the semiconducting alloy system (Pb, Sn) Te in strong electric fields. This material is finding extensive application in 8-14 micrometer wavelength range imaging devices, but little is known about the transport properties. The thrust of the effort will be to determine the saturated drift velocity and investigate whether dynamic instabilities, related to bulk negative differential conductivity, may be initiated in this alloy system. Phenomenologically, the $Pb_{1-x}Sn_xTe$ alloys are a rich system. The multi-valley band structure, the evidence for subsidiary minima in both the conduction and valence bands, and the possibility of strong nonlinear properties due to electric field dependent phonon scattering interaction potentials all point toward fertile ground for new physics or improved devices. Progress: The electron velocity as a function of electric field has been measured in several samples of n-PbTe and the saturated value was found to be somewhere between 1 and 2 x 10^7 cm/sec at 77°K. The effects of contacts are non-negligible and are being studied to reduce the uncertainty. Preliminary observations of high-field domain formation has occurred in samples of PbTe and PbSnTe. The domains propagate with a velocity near to 2 x 10^7 cm/sec. The domains appear to be several hundred micrometers in length, form near the cathode, and decay as they travel toward the anode.

NR 372-095, Colorado State University, "Compound Semiconductor Surfaces and Interfaces," P.I. - Dr. Carl Wilmsen, N00014-76-C-0387

Insulators on InP, InSb, and InAs will be investigated for their electrical and mechanical properties and for low surface state densities. Several analytical techniques, such as Auger electron spectroscopy, ESCA, capacitance-voltage, and capacitance-conductance measurements will be utilized to study the interface properties to obtain a correlation between surface state properties and chemical composition. Theoretical calculations of surface oxidation energies as a function of position and coverage will also be carried out. Initial studies will focus on a double layer insulator with an anodic oxide overlaid with a sputtered oxide, such as silicon dioxide. Progress: New

NR 372-096, Naval Research Laboratory, "Solid Phase Epitaxial Studies Using Molecular Beam Deposition Techniques," P.I. - Dr. John Davey

Solid-solid surface reactions (solid phase epitaxy) may offer an important new method for realizing reasonably complex layered device structures with a minimum of processing complexity. ONR has recently begun a coordinated program to investigate the physical properties of these interactions in several universities and industry. While striking recrystallization effects have been seen, evaporation of the amorphous silicon has disadvantages. Similarly, growth of single crystal silicon by molecular beam epitaxy (vacuum evaporation) at low temperatures has been singularly unsuccessful. Preliminary studies at NRL indicate that by placing a metal layer on the silicon substrate and heating to 600 C during evaporation, thus combining solid-phase-epitaxy with molecular beam epitaxy, single crystal silicon can be grown, a result that could be an important stride forward in semiconductor technology. This program will continue these investigations. Progress: New

NR 372-097, Yeshiva University, "Piezo-Optical Determination of Deformation Potentials in Multi-Valleyed Semiconductors," P.I. - Dr. Fred Pollak, N00014-76-C-0481

An investigation of the stress-dependence of the optical absorption will be carried out in several III-V semiconductors. Wavelength modulated transmission and reflection will be utilized to measure both indirect and direct transitions from valence to conduction band. From the transition rates and the scattering processes, the absolute values for the electron-phonon and hole-phonon deformation potentials for intervalley processes can be determined. Progress: New

NR 371-137, Yale University, "Investigation of Electron-Phonon Interactions by Resonance Raman Scattering," P.I. - Dr. Richard Chang, N00014-76-C-0643

A number of intervalley scattering mechanisms are important in the transport properties of multi-valley semiconductors. A knowledge of these parameters would assist in the evaluation of various semiconductors for applications in new semiconductor devices. Unfortunately, the only information on these parameters, is often inferred from the transport calculations themselves. This program will attempt to determine these parameters through a resonant Raman technique. Resonant one-phonon and multiphonon interactions will be used to provide data on the electron-phonon coupling strengths for interband transitions between non-equivalent conduction band minima, for intervalley transitions between conduction band minima, for electron one-phonon interactions at the conduction and valence band maxima, and for electron two-phonon interactions at these maxima. Progress: New

NR 372-243, California Institute of Technology, "Solid State Electronic Devices," P.I. - Dr. Carver A. Mead, N00014-75-C-0672

This research investigates the optimization, capable from large scale integrated circuit technology, of new architectures for microprogrammable microprocessors. An integrated circuit programmable microprocessor of unique architecture and usual capability is being fabricated. This system is based upon a distributed node of control ... for the various activities of computation and control. Progress: The arithmetic-logic module has been completed and operated properly on the first mask set. This device gives the machine all of the normal logical, arithmetical, and general purpose operations. The data memory control chip has also been made operational.

NR 372-94, University of Pennsylvania, "Crystal Dynamics in Electro-Luminescent Materials," P.I. - Dr. Campbell Laird, N00014-75-C-0[illegible]

Epitaxial films of GaAsP, InGaP and In AlP will be grown on substrates of GaAs, GaP, and InP, respectively, both in step and graded heterojunction geometries. Observation slices will be prepared for study by electron microscopy of the quality and crystalline characteristics of the films. Of particular interest is dislocations due to stress arising from mismatch of the substrate-epitaxial layer interface with the studies of the formation and behavior of the dislocations to be carried out with the aim of controlling their density. Progress: The misfit dislocation structures in conventionally oriented (100) GaAsP and InGaAs heterojunctions were studied by TEM, X-ray topography, stress-induced birefringence and dislocation etching. It is evident that elimination of the undesirable defect structures in vapour [illegible]

devices by modification of fabrication procedures is going to be difficult. Instead, orientations of (122) and (113) are suggested. In the former, two slip systems on the same plane are most highly stressed, consequently little work-hardening should be experienced by the dislocations gliding in to compensate the misfit and the compensation should be rather complete. The second orientation makes use of two highly work-hardening systems, where the burgers vectors compensate very inefficiently, so that they interact to give dislocations with efficient compensation and potentially benign effects on electrical properties.

[illegible]-[illegible], [illegible] Dr. [illegible] Perry, [illegible]

[illegible], University of California, Berkeley, "Periodic Optical Waveguide Studies," [illegible]

Research is concentrated on experimental and theoretical work toward [illegible] preferential etching of channels to provide lateral [illegible] heteroepitaxial technology. This research is aimed at [illegible] laser structures capable of [illegible] determination, [illegible] to monolithic integration, [illegible] been [illegible] at [illegible] 900A/cm². [illegible]

[illegible] Publications:

[illegible] and [illegible], "[illegible] for Ion-Beam [illegible] and Chemical Etching," Appl. Phys. Lett., Vol. 2[illegible], pp. [illegible], Oct. 1 (1974).

[illegible] Wang, [illegible] F. [illegible], "Analysis of Distributed Feedback and Distributed Bragg-Reflector Laser Structures by Method of Multiple Reflections," J. Appl. Phys., Vol. [illegible], pp. 3975-3977, Sept. (1974).

[illegible] Wang, "Thin-Film Bragg [illegible] for Integrated Optics," Wave Electronics, Vol. 1, [illegible] Nov. (1974).

[illegible] W. F. [illegible], "[illegible] Thin-Film Line Distributed Feedback [illegible]," J. Appl. Phys., Vol. [illegible], pp. [illegible], Feb. (1975).

[illegible], "[illegible] Distributed [illegible]," Appl. Phys. Lett., Vol. [illegible], pp. [illegible]-91, Feb [illegible] (1975).

[illegible] C. C. Tseng, W. T. Tsang, and C. Wang, "A Thin-Film Prism as a Beam Separator for Multimode Guided Waves in Integrated Optics," [illegible] Commun., Vol. 11, pp. [illegible], March (1974).

7. W. T. Tsang, C. C. Tseng, and C. Wang, "Optical Waveguides Fabricated by Preferential Etching," Appl. Optics, Vol. 13, pp. 1500-1504, May (1974).

8. W. T. Tsang and C. Wang, "Preferentially Etched Diffraction Gratings in Silicon," J. Appl. Phys., Vol. 46, pp. 2163-2167, May (1975).

9. C. C. Tseng and C. Wang, "Integrated Grating-Type Schottky-Barrier Photodetector with Optical Channel Waveguide," Appl. Phys. Lett., Vol. 26, pp. 630-632, June 1 (1975).

10. C. C. Tseng, D. Boteu, and C. Wang, "Optical Bends and Fibers Fabricated by Preferential Etching," Appl. Phys. Lett., Vol. 26, pp. 699-701, June 15 (1975).

11. W. T. Tsang and C. Wang, "Experimental Studies of Photoresist Gratings," Wave Electronics, Vol. 1, pp. [illegible], July (1975).

NR 009-003, Polytechnic Institute of New York, "Light Beam Couplers for Integrated Optical Circuits," P.I. - Dr. Theo Tamir, N00014-75-C-0421

Optical waveguides which leak energy (but do not dissipate it by absorption or scattering) are adapted as couplers between integrated circuit elements or as beam formers. Changes in guide thickness or modulated grating structures are studied as the mechanism to produce the desired beam behavior. Progress: The perturbation approach has been highly successful in providing highly accurate results for the analysis of wave phenomena on dielectric gratings. The work and results obtained during the past half-year period include the formulation of solutions for treating TM-mode problems, which are more complicated than those of TE modes discussed in the past, the development of equivalent networks, which greatly facilitate the understanding of the physical mechanism involved in the guiding and scattering of waves by dielectric gratings, the derivation of leaky-wave dispersion curves for use in beam-coupler applications, and the development of systematic criteria for the design of dielectric gratings having desirable physical characteristics.

Recent Publications:

1. S. T. Peng and T. Tamir, "Directional Blazing of Waves Guided by Asymmetric Dielectric Gratings", Optics Comm., Vol. 11, pp. 307-309, August 1974.

2. A. Saad, H. L. Bertoni and T. Tamir, "Beam Scattering by Nonuniform Leaky-Wave Structures," Proc. IEEE, Vol. 62, (Special Issue on Rays and Beams), pp. 1552-1561; November 1974.

3. S. T. Peng and T. Tamir, "Effect of Groove Profile on the Performance of Dielectric Grating Couplers," Proc. Symp. Optical and Acoustical Micro-Electronics, Polytechnic Press, pp. 377-390, 1975.

4. S. T. Peng, T. Tamir and H. L. Bertoni, "Theory of Periodic Dielectric Waveguides", IEEE Trans. Microwave Theory and Techniques (Special Issue on Integrated Optics and Optical Waveguides), Vol. MTT-23, pp. 123-133; January 1975.

5. K. Handa, S. T. Peng and T. Tamir, "Improved Perturbation Analysis of Dielectric Gratings", Appl. Physics, Vol. 5, pp. 325-[illegible]; January 1975.

6. S. T. Peng and T. Tamir, "TM-Mode Perturbatic Analys[illegible] of Dielectric Gratings", App. Phys., Vol. 6, pp. 35-[illegible], May 1975.

7. T. Tamir (Editor), "Integrated Optics", Springer-Verlag, New York, Heidelberg, Berlin; 1975.

NR 009-017, Rensselaer Polytechnic Institute, "Optical Real Time Signal Processors Using Surface Rayleigh Waves," P.I. - Dr. Pankaj Das, N00014-75-C-0772

The interaction of acoustic surface waves and integrated optical waves will be studied for signal processor applications. Two acoustic surface waves can be correlated through the acousto-optic interaction with the correlation signal appearing in the diffracted optical signal. The application of this to correlators, modulators, and filters will be investigated. The use of acoustic surface waves for determining the surface properties of semiconductors will be investigated. Progress: Signal processing functions such as convolution correlation, and Fourier transform have been obtained in real-time using the efficient diffraction of laser light from acoustic surface waves propagating on lithium niobate. Different device configurations and detection schemes have been considered. Results were found for the usual delay-line transducer configuration, as well as for an improved scheme which eliminates the problem of the reflection signal. A discussion was given indicating the extension of the acoustooptical convolver to the generation of ambiguity functions and the correlation of a light amplitude distribution with an acoustic signal.

Recent Publications:

1. P. Das, M. E. Motamedi, and R. T. Webster, "Determination of Semiconductor Surface Properties Using Surface Acoustic Waves", Applied Physics Letters 27, 120 (1975).

2. H. Bilboa, M. E. Motamedi, and P. Das, "Study of GaAs Epitaxial Layer Using the Separated Medium Acoustoelectric Effect", in Proc. 1975 Ultrasonics Symposium.

3. M. E. Motamedi, R. T. Webster, and P. Das, "Application of SAW Delay Line Attenuation and Transverse Acoustoelectric Voltage for Determination of Semiconductor Surface Properties", in Proceedings 1975 Ultrasonics Symposium.

4. H. Gilboa, M. E. Motamedi, and P. Das, "Determination of Energy Band and Surface State Locations in GaAs Using the Separated Medium Surface Acoustoelectric Effect", Applied Physics Letters 27, 641 (1975).

NR 009-018, University of Texas, "Multiple and/or Inhomogeneous Layers for Integrated Optical Coupling and Modulation," P.I. - Dr. Bruce Buckman, N00014-75-C-0753

Large, permanent refractive index changes are obtainable in PbI_2 films in the red and infrared portions of the spectrum when these films are subjected to 488 nm Ar laser radiation at film temperature around 165 celsius. Several novel coupling and modulation devices, which are feasible only when a refractive index grating formation mechanism such as this is possible, will be investigated analytically and evaluated experimentally. Progress: A matrix method for calculating the effective refractive index of guided modes on multilayer dielectric waveguides was developed and employed to calculate the effective electrooptic coefficient of such waveguide structures when one of the media composing them is electrooptic. In properly specified three-layer waveguides, enhancement of the effective electrooptic coefficient above the bulk value by as much as a factor equal to the square of the highest refractive index in the structure is possible. The maximum modulation enhancement is attainable with loosely, as well as tightly, confined waveguide modes.

Recent Publications:

1. A. B. Buckman and W. H. Hong, "Large Refractive-Index Change in PbI_2 Films by Photolysis at 150-180C", Journal of the Optical Society of America 65, 914 (1975).

NR 0[illegible]-[illegible]-C[illegible], "Electronic Interconnections", M. E. Weber, [illegible]

NR [illegible]-[illegible], University of Southern California, "Gallium Nitride Growth", P.I. - Professor Murray Bertenthal, [illegible]

This work is directed toward the growth and characterization of microwave grade gallium nitride substrates and epitaxial films for eventual application to solid state microwave devices. In recent Gallium nitride material has been grown with [illegible] of the intrinsic donor conductivity of approximately 1 part in [illegible] results from native nitrogen vacancies.

Recent Publications:

1. Progress Report - March [illegible] - "Evaluation of Gallium Nitride for Active Microwave Devices", M. Bertenthal et.

2. Progress Report - April [illegible] - "Evaluation of Gallium Nitride for Active Microwave Devices", M. Bertenthal et.

NR [illegible]-[illegible], North Carolina State University, "[illegible] for Supervelocity Semiconductors", P.I. - Assoc. Dr. F. M. A. [illegible] et al., [illegible]-[illegible]-C-[illegible]

This work seeks to bypass the expensive and time consuming method of synthesizing new semiconductor materials to determine their properties and applicability to electronic devices. Instead, precise [illegible] of the charge transport characteristics are predicted (by Monte Carlo computer simulation) from known material properties and limited [illegible]. When fundamental properties are not precisely known, estimates are derived from materials of similar structure and sensitivity studies are utilized to the results. Progress: Monte Carlo methods and computer programs have been derived to simulate many of the electron velocity-field and transport conditions, but the [illegible] well. The programs have been calibrated [illegible] experimental results for such materials as Ge, Si, GaAs and InP. Predictions have been made for various [illegible] and [illegible].

Recent Publications:

1. Annual Progress Report dated September 1975 -- "Theoretical Search for Super-Velocity Semiconductors", M. A. Littlejohn and J. R. Hauser.

2. M. A. Littlejohn, J. R. Hauser, T. H. Glisson, "Monte Carlo Calculation of the Velocity-Field Relationship for Gallium Nitride", Applied Phys. Letters.

3. J. E. Andrews and M. A. Littlejohn, "Growth of GaN Thin Films from Triethylgallium Monamine", Journal of Electrochemical Society.

4. J. E. Andrews and M. A. Littlejohn, "Mass Spectroscopic Analysis of GaN Films", (A write-up).

[illegible], SOLID STATE ELECTRONICS, (L. E. Cooper, [illegible])

[illegible], North Carolina State University, "Electrical Properties of Ion Implanted Gallium Arsenide", P.I. - M. Littlejohn, [illegible]

The phenomena associated with the process of ion implanting gallium arsenide (GaAs) with impurities are not understood. The effects of implantation induced structural formations have not been assessed. The investigator will use techniques such as transmission electron microscopy (TEM), Auger electron spectroscopy (AES), photoluminescence, and various electrical measurement techniques to characterize the properties of implanted layers in GaAs. Sulfur, beryllium, magnesium, [illegible], and zinc will be implanted under various conditions of temperature and fluence. Several protecting encapsulating layers will be applied and annealing cycles carried out. Resulting structural information from TEM will be correlated with chemical data (AES) and with the electrical measurement data. Progress: Measurements have shown that a second phase metallurgical structure is formed in the Zn implanted gallium arsenide after annealing. One of these structures is a layer, which has a crystal structure (body centered tetragonal) after anneal that differs from the gallium arsenide matrix. Adjacent to this structure and extending throughout the implanted region is a precipitate of the same anomalous structure. Results show the problem of second phase growth to be further complicated by effects attributed to the type of oxide passivation for annealing. Thus spin-on and pyrolytic silicon dioxides results in different phase formations. In addition, different annealing temperatures, whether 600°C or 800°C result in a variety of results. The zinc implants were at a fairly high dose, such that solubility limits were exceeded in some cases. This would lead to different phase growths. Also, it complicates the interpretation of electrical measurements, since the Hall coefficient measurements can only be correlated with the average defect population, including impurity effects as well as precipitate formation.

[illegible]

beryllium, magnesium, and tellurium ions have been implanted and annealed with transmission electron microscopy (TEM). The defect structures which remain after annealing are different in many cases, both in size and density. Further, electrical measurements give rise to different mobility versus temperature curves for each sample. A preliminary observation has been that the higher the defect density the higher the electrical activity. A "first try" model for the electron transport in samples with ionized impurity and non-homogeneous defect cluster scattering mechanisms are contributing. Monte Carlo methods will be applied to try to model the transport characteristics. The defects vary in size and seem to be dislocation loops, vacancy clusters, or interstitial clusters. Techniques are being developed to provide better identification of these.

Report Bibliography:

[illegible], Littlejohn, Pao, and Farin, "Some Second Phase Precipitates in Beryllium Arsenide Annealed After Implantation with Zinc", Applied Physics Letters, 27, 79 (1975).

[illegible], United Technologies Laboratories, "Effects of Contacts and Circuit on Semiconductor Microwave Devices", [illegible].

A theoretical modeling program has been developed to simulate phenomena in transferred electron devices such as Gunn effect devices and Field Effect Transistors (FET). It has been shown previously that static field models of such devices are inadequate to explain many of the phenomenological results. The investigator, with [illegible], has developed a "Dynamic Cathode Boundary Field" model which simulates changing field conditions at the cathode. This model has been successful in explaining many device features. The model will be applied to three terminal (FET) devices to determine effects of time varying cathode conditions, of regions of negative differential mobility under the gate contact, of various contact properties (barrier heights, etc.) and of external circuit parameters. Parameters will be explored which are pertinent to device experiments at the Naval Research Laboratory. Transferred electron microwave devices are finding increased usage in electronic microwave systems both for amplifiers and for sources. Primarily gallium arsenide is used, but indium phosphide is finding wider application due to its predicted higher efficiency. However, the device parameters which yield higher efficiency in gallium arsenide are not the same as those which yield higher efficiency in indium phosphide. [illegible] contact conditions which give high efficiency in indium phosphide devices apparently give poor [illegible] in gallium arsenide devices. The investigator plans to [illegible] in order to [illegible] improvement with [illegible] high efficiency [illegible] and transferred electron [illegible].

[illegible] which allows for time varying cathode conditions. Further, external circuit parameters must be considered. Contact conditions [illegible], such that if the contact saturated current is [illegible] than the semiconductor saturated current value, sustained [illegible] oscillations will not occur. Conditions of the [illegible] which will result in propagating domains can be [illegible].

[illegible] Publications:

1. [illegible] L. Grubin, "Transferred Electron Devices with Emphasis [illegible] of the Contacts", a review, Report # [illegible], [illegible] Report.

[illegible], Wayne State University, "Microwave Current [illegible] in Indium Phosphide", P.I. - [illegible] Chew, N00014-[illegible]

[illegible] of the phenomena [illegible] differential mobility [illegible], are very sensitive [illegible] circuit interactions. These effects have been [illegible] for GaAs both experimentally and [illegible] have been no equivalent studies, [illegible] for an advanced transferred electron [illegible] material. Instabilities can be generated by [illegible] material but the contact boundary conditions [illegible] the growth and propagation of [illegible] circuit response will [illegible] as well as the ultimate upper frequency limit [illegible]. A variety of [illegible] techniques will be applied to determine the parameters which affect the [illegible] the resulting device performance. [illegible] will be measured for a variety of conditions including applied magnetic and pressure fields. This program is an excellent [illegible] research into devices operating in higher frequency ranges.

Progress: New

[illegible]

[illegible], University of [illegible]

[illegible]

[illegible] experimental devices will be fabricated and tested with good [illegible]. The study is of value in relating experimental [illegible]. Progress: A high power [illegible] amplifier operation has been demonstrated. Both [illegible] efficiency and frequency of power [illegible]. A [illegible] wave-shape has been determined which [illegible] [illegible] [illegible]. An experimental [illegible] has been studied in which the frequency [illegible]. A low frequency noise was discovered which [illegible] with the tuning of the fundamental frequency. A [illegible] spectrum of intermodulation products [illegible].

[illegible] Publications:

[illegible] J. L. Hall, F. E. Mains, E. J. Maccari, "Progress [illegible] Amplifiers", Progress Report, [illegible] April [illegible].

[illegible], Cornell University, "Signal Effects of Interfaces in Microwave Devices", J. L. - L. Hartman, [illegible]

Using thin film analysis techniques, the chemical properties of thin films of gallium arsenide and ternary alloy semiconductors on or with gallium arsenide substrates are determined. In particular, deviations from stoichiometry, and the presence of impurities and vacancies in the interface region will be probed. Electron transport properties will be studied for configurations compatible with field effect transistor (FET) and transferred electron device applications. Heat and strain effects at the interfaces will be determined. Progress: Mass spectrometer studies of liquid phase epitaxially grown layers of gallium arsenide on semi-insulating gallium arsenide substrates have shown large differences in chemical properties of the interface as processing procedures are changed. The differences are correlated with resistivity variations as large as one thousand. Chromium and silicon inclusions in the substrate have been detected. The silicon inclusions if coupled with surface vacancies have been identified as the cause of poor electron transport in FET layers grown on these substrates. The results of the past summer period have demonstrated very vividly how important the bulk substrate is for epitaxial layers for FET or transferred electron device [illegible] applications. The chemical and electrical properties of the interfaces of these heterojunctions will continue to receive attention. The role of environmental impurities, bulk impurities, and native defects may be elucidated and their relative ability to produce surface [illegible] properties, or with [illegible], etc., will be investigated. Initial [illegible] studies of the heterojunction band systems [illegible]

system grown on InAs substrates. Interfaces to be examined include GaSb/InAs, InAsSb/InAs, and InAs/InP, all grown by liquid phase epitaxy (LPE). Electron transport properties in the LPE heteroepitaxy as well as the heterojunction II to be investigated. It is well known that the physical and electronic properties of heterojunctions are not well understood. In view of the complexity of the interfaces, as indicated by the previous research, it is apparent that more needs to be done in these systems. The ternary alloy semiconductors are of interest for several reasons: they have variable energy gaps/bands, and lattice constants (varying with alloy content); it has been suggested that they may have high saturated drift velocities useful for high frequency devices. The variable lattice constants allow for easier lattice match problems in heterojunctions or with

Recent Publications:

1. S. C. Lawrence and L. F. Eastman, "Electric-Current-Controlled Liquid Phase Epitaxial Growth of InAs", presented at IEEE Research on Compound Semiconductor Microwave Devices Held at Philadelphia,

[illegible]-77), Naval Research Laboratory, "Study of Oxide Charge in Thermal Silicon Dioxide", L.J. - W. Baker, "[illegible]-Ta-[illegible]

Silicon electron device technology requires many years of combined processing and material growth. Central to this is the formation of silicon dioxide insulator layers for such things as MOS transistors, and for passivation to isolate components and interconnections in multilevel chips. Serious problems are associated with the presence of fixed electric charge in the oxide layers. Reliability, stability, yield and, and radiation vulnerability are affected by the properties of the oxide. Reliability, for instance, is tested-in not built-in. In the procurement cycle, thus creating costs by large factors. The intent of this task is to provide knowledge which should lead to solutions to these problems. Current manufacturing approaches are very empirical. Using electrical, optical, and physical measurements combined with theoretical modeling, part or almost all of the origin or cause of the charge which appears in the oxide films will be studied. Questions such as the following will be attacked: what parameters associated with device fabrication and processing techniques affect the oxide charge? What factors affect the lateral (along the surface) homogeneity of charge or oxide properties? What impurities in the oxide are related to the charge problem? What mechanism, if any, permits chlorine or any other impurity to ameliorate the problem? What is the role of multiple oxide films in affecting the charge and why does silicon nitride over the silicon - silicon dioxide interface? In progress: How

Recent Publications: None

[illegible] monolithic optical devices for generating and [illegible] optical radiation with simple, reproducible, inexpensive materials and techniques. The term integrated optics (IO) for optical circuitry [illegible] the way that integrated circuits is used to identify the electronic processes in semiconductor electronics. The investigator is pushing the IO frontier by studying quantum electronic phenomena in thin film devices of GaAs and GaAlAs which would be compatible with integrated optics technology of the future. In particular, he is continuing to [illegible] a device called a distributed feedback laser which makes use of a periodic spatial modulation of the interface between two materials to produce the radiation necessary for stimulated laser action. The materials are GaAs and GaAlAs used in several structures, where the GaAs acts as a waveguide and the GaAlAs provides a boundary with a variable coefficient of refraction (dependent on the relative amounts of gallium and aluminum). The advantages are the following,- laser action without close tolerance mirrors in the laser cavity, possibility for mode control (enhance the optimum mode) of both longitudinal and transverse types, large reductions in threshold current density, better temperature response, materials are compatible with advanced GaAs technology, and laser operates in a wavelength region of small absorption. Progress: The investigator has studied theoretically and experimentally various injection laser structures in gallium arsenide and gallium aluminum arsenide. He will investigate the properties of distributed feedback lasers by preparing devices with surface corrugations having 0.1 micron spatial separation. A new technique of embedded heterostructure epitaxy will be developed to evaluate it's usefulness in fabricating channel lasers. The distributed feedback lasers will be studied with emphasis on mode control wavelength stability. Reduction of threshold current density will be investigated in these structures.

Recent Publications:

1. Kuver, A., Burrell, E., and Yariv, A., "Solid-State Travelling-Wave Amplification in the Collisionless Regime," Journal of Applied Physics, 45, 4847, (1974).

2. Yariv, A. and Kuver, A., "Equivalence of the Coupled-Mode and Floquet-Bloch Formalisms in Periodic Optical Waveguides", Applied Physics Letters, 26, 537 (1975).

[illegible] 29, University of California at Berkeley, "Millimeter Wave Maser Amplifiers", F.I. - C. Townes, [illegible]

[illegible] study is directed toward the evolution of travelling wave types of masers, with particular emphasis given to characteristics of [illegible] dispersive structure elements in the maser cavity. [illegible] figures, tunability and sensitivity of masers operating in the [illegible] millimeter wavelength region are determined. Improvements to increase performance and to decrease size and complexity are to be investigated. Development of a superconducting slow-wave structure will be accomplished to attain lower losses and hence high gain, lower pump power, and shorter wavelength. Progress: The reduction in system noise to very low figures has permitted measurements on interstellar and galactic sources not possible previously; i.e., more sensitivity and shorter observing times. They have increased the tunability around the 25 GHz central frequency to about [illegible]. They are developing a superconducting slow wave structure with reduced circuit losses. The slow wave structure permits greater amplification and thus smaller simpler systems. There has now been long term operation of maser amplifiers operated in conjunction with the [illegible] foot antenna at the Hat Creek Observatory of the University of California and with the 85 foot antenna of the Naval Research Laboratory. There have been continuing improvements in these maser systems to increase tunability and bandwidth to reduce system noise, and some simplifications and reduction in size. Some design work is being done to produce two high stability masers for use in a spatial interferometer system for twin antennas at Hat Creek Observatory. A technique for using a slow wave superconducting structure has been demonstrated and is being incorporated into a maser amplifier. There have been many observations, using the extremely low noise amplifiers, of interstellar and galactic sources showing the abundances of a variety of molecular systems.

Recent Publications:

1. J. A. Mango, K. J. Johnston, M. F. Chui, A. C. Cheung, and P. Matsakis, "Molecule Searches in Comet Kohoutek (1973f) at Microwave Frequencies", Icarus 23, 590-594, 1974.

2. M. Bertorgo, M. F. Chui, and C. H. Townes, "Isotopic Abundances and Their Variations within the Galaxy", [illegible], Vol. 154, [illegible], 1974.

2, "Irradiation Effects", [illegible], [illegible]

[illegible], State University of New York - Albany, "Defects in Semiconductors", [illegible], [illegible]

The study of defects in semiconductors continues to be important as progress by ion-beam modification and by implantation of impurity ions. There are three principal aspects to this topic: (1) the basic physics of silicon and diamond which have been irradiated by energetic particles or have been implanted with a variety of impurity ions; (2) correlation of the physical and electrical properties of these semiconductors with the defects and impurities introduced by the irradiation or implantation; (3) the use of radioactive tracer techniques to survey a variety of impurities (including metals and dopants) to test practical methods for fabrication enhanced diffusion processes in silicon, germanium, and gallium arsenide. This program will identify the radiation and impurity induced defects in semiconductors which are identified by EPR, optical and electrical measurements in silicon, diamond, and gallium arsenide. Progress: Diffusion experiments have been developed for a variety of enhanced diffusion mechanisms for the diamond type lattice. Experimental results thus far indicate no enhanced diffusion of gold in silicon. The spectra of ion implanted diamonds are not found in electron and neutron irradiated diamonds. Free and bound holes have been identified with the EPR spectra of B and Be doped diamonds. Theoretical calculations have shown that the self interstitial in silicon is likely to be in a split interstitial configuration. Recent calculations which allow for Jahn-Teller distortions show that relaxation of symmetry does not affect the split interstitial conclusions.

Recent Publications:

1. "An Orientation-Dependent Defect in Ion-Implanted Silicon", by Y. Lee, J. Erskine and J. Corbett, Physics Letters, V. [illegible], [illegible], 1 Oct 1978.

2. "Theory of the Principal Values of Deep Impurity and Intrinsic Defect Centers in Silicon and Diamond", by F. V. Prelimo and J. W. Corbett, Physics Dept. State University of New York, [illegible], Vol. [illegible], [illegible].

[illegible] Mannin[illegible], [illegible] for the Internal [illegible]", [illegible] Simulation Program (Semiannual Progress [illegible]) [illegible] (March 1975), pp. [illegible]

[illegible] Mueller, [illegible], and [illegible] Mannin[illegible] "[illegible] Polynomial Expansion Method [illegible] [illegible] for Ion Implantation [illegible]", Cooperative Radiation Effects Simulation Program [illegible] Progress Report, [illegible]

[illegible] M. Rosen, G. P. Mueller, and [illegible] Mannin[illegible], "[illegible] Polynomial Expansion Method for Solving [illegible] Equation for Ion Implantation: II. [illegible] the Penetrating Beam: [illegible] Normally Incident on Germanium", Cooperative Radiation Effects Simulation Program (Semiannual Progress Report), [illegible] (March 197[illegible]), pp. [illegible]

[illegible] Manning and G. P. Mueller, "[illegible] Distribution of Energy Deposition by Heavy Ion Bombardment", Nucl. Inst. and Meth. [illegible], [illegible] ([illegible]).

[illegible]-[illegible], California Institute of Technology, "Study of Semiconductor Structures Using Nuclear Techniques", [illegible] Mayer, [illegible]

The goals of this task is to develop and evaluate [illegible] techniques, using heavy ions, for the analysis of thin films [illegible] of metals, insulators, and semiconductors [illegible] semiconductor substrates. The analysis result [illegible] of spatial densities of various atomic species [illegible] in these modified solid materials. Energy loss effects, channeling effects, compound substrate effects, and the role of [illegible] damage on the resolution and sensitivity of the [illegible] technique are studied. Coupled to these [illegible] efforts directed toward study of the ion implantation process in semiconductors and of silicide formation [illegible]

The other goal is to study the process of [illegible] on silicon and germanium. In progress: There are many [illegible] which can occur between metal-semiconductor and [illegible] structures. Many of the processes [illegible] can occur at relatively low temperatures [illegible] A new rule has been suggested which predicts which [illegible] will be formed in metal-semiconductor binary [illegible] testing this rule in the formation of silicides and germanides [illegible] will systematically investigate the composition of the [illegible]

from metal films deposited on crystalline semiconductors. [illegible] part is concerned with the regrowth process which occurs in silicon and germanium single crystals which follow the regrowth process in ion implantation. The regrowth kinetics, rates, [illegible], etc., will be studied for electrically active impurities, and for isoelectronic elements. The investigator has demonstrated the [illegible] phase epitaxial growth process using palladium silicide as a transport media to deposit silicon atoms onto a single crystal silicon substrate. Temperatures were below [illegible]. He has noted the very strong crystal orientation dependence on the annealing of residual damage after ion implantation of silicon. The [illegible] orientation does not result in complete annealing and the [illegible] results require complex temperature treatment. It is proposed that the reason for lower residual damage in <111> and <100> oriented substrates is a result of faster regrowth rates in these directions which overcomes the competing mechanism of polycrystalline regrowth.

Recent Publications:

1. "Backscattering Spectrometry," J. W. Mayer, M. A. Nicolet, and J. S. Chu, J. Vac. Sci. Technol. 1, 62 (1974).

2. "Crystal Orientation Dependence of Resistivity Recovery in Ion-Implanted Si," H. Muller, W. K. Chu, J. Gyulai, J. W. Mayer, L. A. Pegram and T. K. Chu, Appl. Phys. Lett. 26, 238 (1975).

3. "Solid Phase Epitaxial Growth of Si Through Isolating Oxide Layers," M. Wittmer, J. S. Chu[illegible], J. A. Tsai, J. L. Klatt and J. W. Mayer, Presented at the Electrochemical Society Meeting, [illegible], May 11-16, 1975. J. Appl. Phys. 46, [illegible] (1975).

4. "Materials Analysis by Nuclear Backscattering Application," J. W. Mayer and E. M. Pitsch, in New Uses of Low-Energy Accelerators, ed. J. F. Ziegler (Plenum Press, New York, 1974), Chapter 11, p. [illegible].

5. "Energy Straggling of [illegible] Ions Below [illegible] MeV in Al, Ni and Au," J. M. Harris and M. A. Nicolet, Phys. Rev. B11, [illegible] (1975).

6. "Energy Straggling of [illegible] Ions Below [illegible] MeV in Al, Ni and Au," J. M. Harris and M. A. Nicolet, Presented at the 1975 Nuclear Physics Symposium, Anaheim, October 9-11, 1975, J. Phys. Soc. Japan [illegible], 1 (1976).

7. "Magnetic Anisotropy in Permalloy Thin Films," [illegible] Chu, R. L. Conger and M. A. Nicolet, J. Appl. [illegible] Phys. [illegible], [illegible] (1975).

5. "Energy Loss of [illegible] MeV [illegible]," [illegible], Penn, J. Appl. Phys. 47, 3084 (1976).

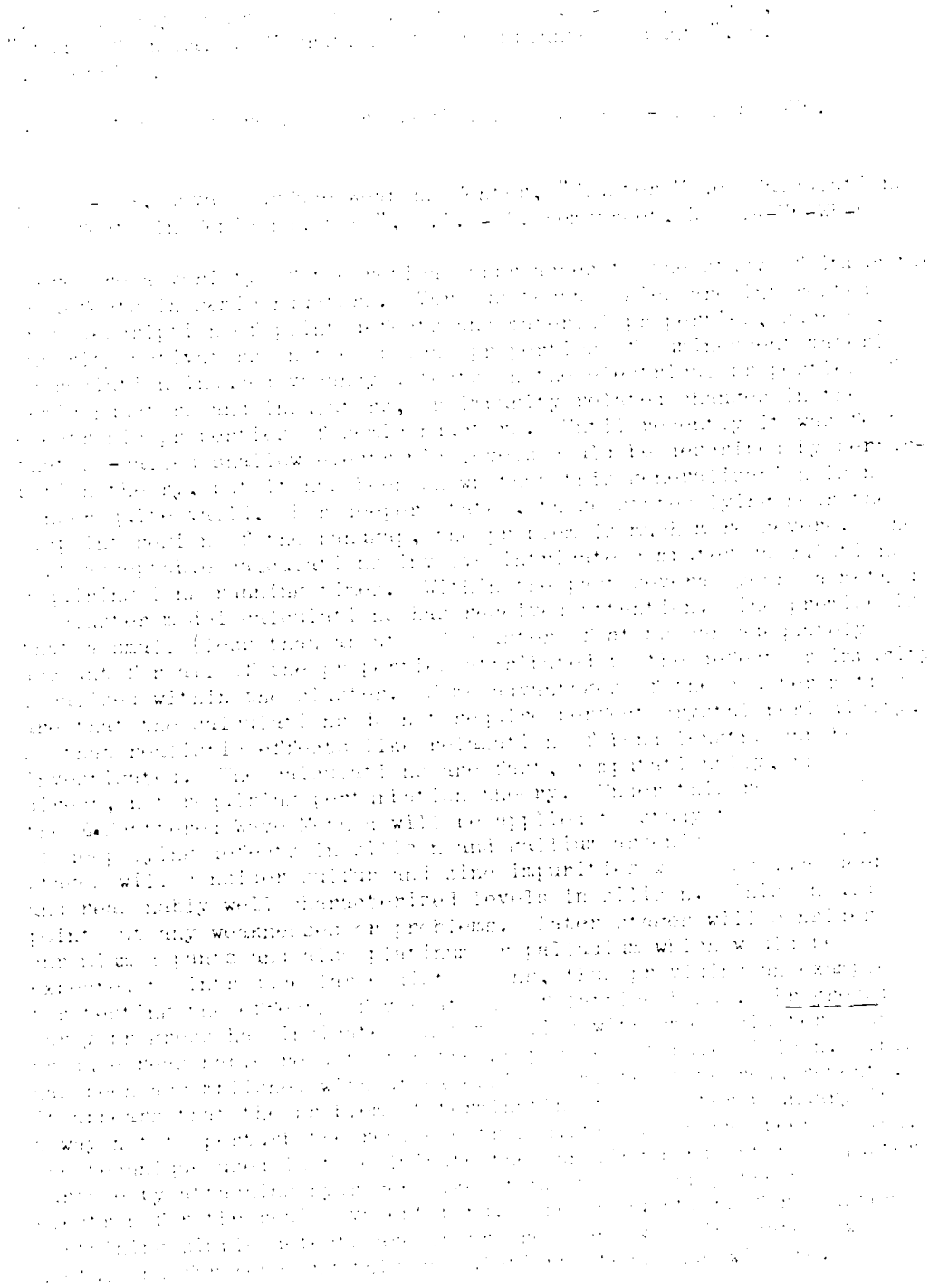
6. "Surface Analysis Using Surface Ionization," [illegible], Wolfgang Bot, in Low Temp. & Low Energy Accelerators, [illegible], Elsevier (Elsevier Press, New York, 1977), [illegible], p. [illegible].

[illegible]-Wolf, Stanford University, "Study of [illegible] Surfaces Using Electron Spectroscopy", [illegible], Stanford-ERL-[illegible]-[illegible].

This task will study the fundamental electronic structure of the surfaces of III-V semiconductors, using direct photoemission spectroscopy, which investigates the filled electron states of a solid surface. The electronic properties of clean surfaces, surfaces with [illegible], or surfaces covered with metals, will be determined. [illegible] will be correlated with measurements of [illegible] emitted electrons and from x-ray induced photoemission. These measurements provide both a fundamental [illegible] physical interest in covering of the surface. [illegible] with the optical models and study of the electronic surface region. These approaches are relatively new and effective tools for [illegible] approaches currently used in technology areas. Important [illegible] with this proposal is the availability of the synchrotron radiation facility at Stanford. Only the high intensity, high resolution, continuous frequency spectrum, ultra high vacuum capability makes these experiments feasible. Progress: Extensive studies of gallium arsenide (110) surfaces indicated two phases of chemical reaction: 1) a bonding of oxygen to surface arsenic at an initial [illegible] monolayer coverage. 2) A series of different chemical bonding arsenic oxidant with beginning of a gallium - oxygen reaction. Definite evidence for different oxidation rates on p and n type gallium arsenide surfaces has been found. It has been shown how useful the synchrotron radiation source can be for these studies. By varying the photon energy, the regions of the surface [illegible] can be probed, since the escape depth (sampling depth) varies with energy. Further, a strong dependence of the excitation of [illegible] states on photon energy has been found [illegible] studies.

Recent Publications:

1. "Surface and Interface Potentials [illegible] III-V Compounds", W. E. Spicer and I. A. Eastman - [illegible].



Recent Publications: None

[illegible], Georgia Institute of Technology, "[illegible]
[illegible]", P.I. - E. Scheibner, [illegible]

This task is part of the program to investigate the processes and mechanisms of solid reactions referred to as solid phase epitaxy (SPE). This effort has broader relevance areas, in that it investigates processes which are involved in device applications such as metallization phenomena, silicide growth, Schottky barrier formation, and MOS fabrication. The metal-oxide interface is important for the SPE problem because of evidence that natural oxides on the silicon surface greatly effect the epitaxy process. Limited experiments suggests that the metal film which is deposited on the silicon must remove any native oxides before silicon epitaxial growth can proceed. This process must be understood, and studying it is a goal of this task. Materials of interest are silicon, gallium arsenide, native oxides, and various metals. The Auger and x-ray spectroscopies [illegible] and analyzed for application to these materials systems so that chemical information can be reduced. The studies [illegible] can be derived from chemical shifts, that is, changes in the emitted electron energy. Experimental and theoretical studies of these electron spectroscopies for studying surface physics and chemistry are part of this program. Many experimental features of the photoelectron and Auger electrons have been determined for aluminum oxide and will be continued for aluminum on silicon oxides. These qualitative chemical and structural information will be of value in further understanding of the processes of electron energy loss and lineshape effects occurs. Experimental work is underway to understand and systematize these effects. Theoretical calculations will augment the effort in this direction. The two systems of primary interest are the metal-SiO_2 and metal-Ga_2O_3 interfaces. Thermodynamic data suggest that certain metal oxides may be reduced by interaction with different metal systems. Progress: New

Recent Publications: None

[illegible], Georgia Institute of Technology, "[illegible]
[illegible]", P.I. - E. Scheibner, [illegible]

[illegible]

Hall measurements, C-V, I-V measurements, and others. Additional studies will be made on structures formed after an amorphous silicon layer is deposited over the metal prior to the annealing. Different forms of amorphous silicon will be studied. Polysilicon will also be considered. Progress: Epitaxial silicon layers have been grown on silicon substrates by the solid phase epitaxial growth process. All steps in the preparation, deposition, and growth processes have been accomplished in an ultra high vacuum system to avoid contaminant interactions. The crystal silicon-palladium film-amorphous silicon system was used. Measurements show that palladium is incorporated in the epitaxial layer after growth, the amount depending on the substrate orientation. Further, in the silicide formation stage the $PdSi$ layer on Si(111) is more strongly oriented to the substrate than Pd_2Si on the Si(100) face. Low temperature, slow growth rate, solid phase epitaxy offers great promise formaking ultra thin electrically active layers with sharp interfaces. The impact on device technology could be very great. There is expectation that these studies will also contribute to understanding of other related problems in device technology, such as, metallization processes, silicide formation, and aging affects or both.

Recent Publications: None

NR 389-059, University of Illinois, "Ion Implantation of Gallium Arsenide", P. I. - B. Streetman, N00014-76-C-

The properties of gallium arsenide (GaAs) implanted with various dopant impurities will be studied. Many unknowns will be investigated such as, the effects of radiation damage induced by the ion bombardment, the processes by which the dopant atoms become electrically active in the semiconductor, the effects of various surface encapsulating films which prevent GaAs surface degradation during heat treatment, the determination of the spatial location of impurities before and after annealing (with special attention to enhanced diffusion effects), the correlation of resultant optical and electrical properties with implantation conditions, and the study of impurity and defect centers generated by the processing. Beryllium and sulfur impurity spatial profiles will be determined by use of mass analysis, electron spectroscopy (Auger), and the Glow Discharge Optical Spectroscopy techniques. Various electrical measurements will be made on samples fabricated into device configurations. Photoluminescence measurements will be used to investigate defect and impurity centers. This task is closely coordinated with other Navy laboratory programs and provides a unique complement to there efforts.
Progress: New
Recent Publications: None

[illegible], University of Massachusetts, "Defects in Semiconductors", F.Y. - [illegible], [illegible]-76-C-

[illegible] efforts are underway at several laboratories supported by [illegible] semi-insulating GaAs substrates for electronic devices. [illegible] which result in such material are not understood. [illegible] materials are stable, but mostly they are not. [illegible] thought involves that chromium and/or oxygen impurities [illegible] the background donor contribution to provide high resistivity. How this compensation occurs, whether or not oxygen [illegible] is responsible, whether oxygen forms complexes with chromium, whether or not lattice vacancies are involved, and what are the energy levels for these impurities, are all questions which have no answers. Other impurity and defect problems are found in the formulation and efficiency of GaAs lasers, where non-radiative recombination processes are associated with defects and dislocations. An associated problem is that of producing or understanding how [illegible] type GaAs by ion implantation.

At the University of Massachusetts experimental and theoretical [illegible] will be made on the effects of impurities on the electrical and optical properties of gallium arsenide (GaAs). Trap ionization energies, carrier cross sections, and photoionization cross-sections of chromium and oxygen impurities will be determined as a function of temperature. The capture cross sections will be determined as a function of electric field because of the importance in device configurations where high electric fields are prevalent. Theoretical calculations will be made using a pseudopotential or a modification to a multiband effective mass approximation for chromium and oxygen impurities in GaAs. Temperature dependence and lattice relaxation effects will be taken into account. The same techniques will be applied to the study of radiation in damage produced by light ion bombardment of GaAs. Annealing studies will be undertaken.
Progress: New

Recent Publications: None

[illegible]-76], National Bureau of Standards, "Structural Determination of Solid Surfaces", F.Y. - D. Pierce, [illegible]-76-C-

A spin polarized electron source will be incorporated into a low energy electron diffraction ('LEED') system for use in the study of the surface structure (crystallography) of metals and semiconductors. It has been suggested that polarization effects in LEED experiments would reduce the ambiguity in the resulting surface structure analysis and provide clarification to understanding the factors involved in

level is usually found to be in the range of [illegible]. Similar sensitivity for copper in GaAs and iron in InP is expected. Already, ESR signals have been identified for Cr^{++} in GaAs samples by the principal investigator. By stress and temperature studies of samples in the ESR, the symmetrical point group of the impurity in its immediate surroundings can be deduced which is important for explaining how compensation occurs. The photoluminescence results will complement the ESR work by helping identify the energy position of the electrical state introduced by the impurity. Variation of the emission spectrum with changes in temperature, stress, and doping concentration helps in the identification of the compensation mechanisms. The main obstacle to the use of GaAs in electronic devices is in obtaining high quality material. Growth and characterization processes must be analyzed together to solve the problems. This task will play a significant role in the materials development and use of GaAs and InP for electron devices. Progress: New

Recent Publications: None

RF-54-581-001, MICROWAVE MATERIALS AND DEVICE TECHNOLOGY (M. E. Hines, 202-697-4218)

MB 751-013, Westinghouse Research Laboratories, "Vertical Channel MOS Transistor," P.I.-Dr. T.M.S. Heng, N00014-74-C-0012

This work exploits a vertical channel geometry to create a linear Class A silicon MOS power FET operating in L and P bands. By virtue of the geometry, submicron gates can be deposited from mask sets whose photolithographic resolution is several micrometers. The geometry also greatly reduces the ratio of gate periphery to device area, thus reducing parasitic loading. Progress: Class A power output at P band has exceeded the best available bipolar Class A power. Intermodulation distortion is about 10 dB better than that of bipolar power devices.

Recent Publications:

1. "A Power Silicon Microwave MOS Transistor", F.J. Gaboriault, R.E. Wickstrom, F.A. Tremere and T.M.S. Heng, published in Microwave Theory and Technique Issue on Microwave FETs, July 1976 (Special Issue).

2. "Vertical MOS Transistor Geometry for Power Amplification at Gigahertz Frequencies", T. Heng and H. Nathanson, Electronics Letters, Vol. 10, No. 23, Nov 14, 1974.

MB 751-017, Varian Associates, "GaInAs FET," P.I.-Dr. Ronald Bell, N00014-75-C-0707

This work seeks to synthesize GaInAs material of several In/Ga/As ratios, construct FETs of same, and compare the ternary FET properties to those of a similar GaAs FET. Progress: An FET constructed of 15% InAs/85% GaAs has exhibited an effective carrier velocity twice that of a 100% GaAs FET of similar geometry.

Recent Publications:

1. "Microwave InGaP/GaAs Schottky-Barrier-Gate Field-Effect Transistor - Preliminary Results", J.B. Lecker, B. L. Feinman and J.J. Lipsky, to be published in the Small Conference on "Active Solid-State Devices for Microwave and Integrated Optics," [illegible],

2. "Thin Film Epitaxial Growth of InGaP/GaAs," J.J. Lipsky, to be published in the Journal of the Electrochemical Society.

UP 751-219, Varian Associates, "Nonplanar, Buried Channel FET," P.I.-Dr. Donald Bell, N00014-75-C-0303

This work seeks to construct a GaAs FET in a geometry such that the gate is on the opposite side of the channel from the source and drain. In this manner, the gate breakdown voltage is increased and channel carrier transport occurs only in a buried channel away from substrate and oxide interfaces. Progress: Anisotropic etch procedures and through refill by chemical vapor deposition have been successfully accomplished so as to reduce parasitic capacitance. First devices are expected in June 76.

Recent Publications:

None

UP 751-219, Westinghouse Research Labs, "Vertical Channel GaAs FET," P.I.-Dr. T.M.F. Reed, N00014-75-C-0418

This work exploits a vertical channel geometry to create a linear short A enhancement mode accumulation type gallium arsenide FET operating in K and I bands. The unique geometry permits the achievement of submicron gates using multimicron photolithography. Progress: An anodic oxide technique has been developed which provides surface state densities low enough (<1.0x10[illegible]) for MIS operation.

Recent Publications:

None

UP 751-220, Texas Instruments, "Semi Insulating GaAs FET," P.I.-Dr. [illegible] Shaw, N00014-75-C-1154

This work exploits ion implantation to enhance the performance of otherwise conventional Schottky barrier gate GaAs FET. Specifically implantation of an n layer under the top surface of the pinched channel creates a semi insulating layer. This layer improves gate drain breakdown and device stability. It eliminates the Schottky contact

NF 5--5[illegible]-001, (Exploratory Development), "Transferred Electron Logic Devices & Materials", [illegible]. T. Yoder, [illegible]

NF 3[illegible]-001, Naval Research Laboratory, "III-V III[illegible] Materials", [illegible] - Howard Lessoff, N0001[illegible]-75-WR-5[illegible]

This work seeks methods and techniques for preparing readily available GaAs and InP substrates and GaAs epitaxial films of high quality suitable for use in the fabrication of transferred electron logic devices and/or FETs. Progress: Boron nitride boats and crucibles have been used to eliminate silicon and carbon impurities. Boules of InP and GaAs have been pulled using a rotating crucible instead of a rotating seed. Dislocation densities (as measured by etch pit densities) have dropped to nearly zero. Interface state density between GaAs substrates and GaAs L.P.E. films has been reduced by an in situ cleaning of the substrate immediately prior to epitaxial growth.

Recent Publications:

1. Quarterly Progress Report for 15 Feb - 15 May 197[illegible]

2. Annual Report "Research on Gunn Effect Materials", [illegible], FY 75, H. Lessoff

3. Quarterly Progress Report for 15 Aug - 15 Nov 197[illegible] "Research on Gunn Effect Materials", Howard Lessoff.

4. "Liquid Phase Epitaxial Growth of Gallium Arsenide on Semi-Insulating Substrate", J.F.R. Nordquist, Jr., H. Lessoff, L. M. Swinnerd, Submitted to Material Research Bulletin.

NF 3[illegible]-002, Naval Research Laboratory, "III-V Materials Characterization", I. L. - Dr. Bruce Mathews, N[illegible]-[illegible]-WR-33-[illegible]

This work seeks to develop non-destructive techniques for characterizing III-V compound semiconductor substrate and epitaxial film materials for use in GaAs FET microwave devices. A set of characterization which are both necessary and sufficient to [illegible] devices will be sought, perfected and applied to [illegible]

[illegible] determined [illegible] the magnitude and ratio of N_D^{++} and N_D^{+++} [illegible] been shown to be a good indication of the quality of [illegible] GaAs. [illegible] technique has been developed whereby the semiconductor [illegible] is determined by the equation $\mu = \frac{}{}$. [illegible] a destructive microwave cavity technique measures [illegible] resistance. From these measurements, carrier concentration [illegible] be determined.

Recent Publications:

1. Quarterly Progress Report for 15 Nov 74 - 15 Feb 75.

2. Quarterly Progress Report for 15 Feb - 15 May 1975.

3. Annual Technical Report for 1 July 1974 - 30 June 75 [illegible].

4. Annual Technical Report, 1 July 74 - 30 June 75 "[illegible] of GaAs & Epitaxial Single Crystals of III-V Compounds".

5. Quarterly Progress Report for 15 May - 15 August 1975.

6. Quarterly Progress Report for 15 August - 15 November 1975.

7. "Characterization of Semi-Insulating GaAs", J. J. Hsieh, MIT, dated 27 June 1975.

DR App-075, Naval Electronics Laboratory Center, "Epi Gallium Heteroepitaxy", J. J. - Dr. Arthur Lawson, [illegible]-75-WR-[illegible]

This work seeks to grow & characterize InP and InAsP III-V epitaxial films for GUNN and FET devices. Heteroepitaxial and homoepitaxial means are used. Both liquid and vapor approaches are taken.
Progress: InP and InAsP (in various mole fraction ratios) have been grown both heteroepitaxially on GaAs and homoepitaxially on InP. State of the art InAsP has been grown. An insulating film with surface state density under 1×10^{12} has been developed to preclude the need for the [illegible] ally [illegible] ky barrier [illegible] on Indium phosphide materials.

Recent Publications:

1. H. H. Weider, "Trapping at [illegible] of InAs Epilayers", Applied Physics Letters, Vol. [illegible], No. 4, 15 Feb 1975.

NR 383-034, RCA Princeton Labs., "TELD Shift Register", P. I. - Dr. Y. Narayan, N00014-75-C-0100

This work seeks to develop a domestic expertise in [illegible] transferred electron logic devices (TELD) operating at microwave frequencies. This particular effort further seeks to demonstrate that a shift register can be built which will operate at clock speeds exceeding 5GHz and that the TELDs therein may be configured for use as a signal correlator. Progress: A TELD shift register has been demonstrated to operate with pulse widths as narrow as 80 ps.

Recent Publications:

1. Bi-Monthly Progress Report #1 for Jan 1975.

2. Bi-Monthly Progress Report #2 for March 1975, dated 1 Apr 1975.

3. Bi-Monthly Progress Report #3 for May 1975, dated 15 May 1975.

4. Letter Progress Report #4 for July 1975, dated 31 July 1975.

5. Letter Progress Report #5 dated 30 Sept 1975, "Microwave Shift Register".

6. Letter Progress Report #6 dated October 1975, "Microwave Shift Register".

7. Letter Progress Report #7 dated December 1975, "Microwave Shift Register".

8. Annual Technical Report - Draft Copy for the period [illegible] 14 Dec 1975, "Microwave Shift Register".

9. Annual Report, "Microwave Shift Register", L. Y. Upadhyayula, H. E. Smith, J. F. Wilhelm, [illegible]

10. Progress Report, "Microwave Shift Register", [illegible] L. Y. Upadhyayula, H. E. Smith, J. F. Wilhelm.

NR 383-029, RCA Princeton Labs., "Transverse Domain TELD", I. I. - Dr. Y. S. Narayan, N00014-76-C-0465

This work seeks to develop optimum TELD structures wherein adjacent "channels" are excited by a transverse spreading of the dipole domain. In this manner inter element delay and parasitic loading may be eliminated such that complex logic computations requiring many clock cycles by conventional approaches may be reduced to one or two clock cycles. Progress: New

Recent Publications:

1. Progress Report #1, February 1976, W. R. Curtice.

2. Bi-Monthly Progress Report #2, dtd. Apr 1976, W. R. Curtice.

NR 383-030, RCA Princeton Labs., "Enhancement Mode TELD", I. I. - Dr. Y. S. Narayan, N00014-76-C-0465

This work seeks to understand, exploit, and determine the limitations of a new normally quasi-off mode of TELD operation whose peak power consumption is but 25% of that required of a conventional enhancement and depletion mode TELD. Progress: New

Recent Publications:

1. Letter Progress Report #1, Feb. 1976, "Enhancement Mode Logic Devices", by L. C. Upadhyayula, R. F. Smith.

2. Progress Report #2, dtd March 1976, "Enhancement Mode TELD Logic Devices", L. C. Upadhyayula, R. F. Smith.

NR 383-031, TRW Systems, Inc., "BPCK TELD", I. I. - Dale Claxton, N00014-76-C-0570

This work has two objectives. First, a new approach to bi-phase shift keying using active TELDs greatly simplifies the circuitry required to do the job. In this respect, it eliminates bulky and expensive components such as circulators. By simplifying, greater reliability is expected and size reduction by a factor of 100 may be realized. Second, the modulation data rate may be increased up to the channel limit. Progress: New

Recent Publications:

1. Status Report, "TELD Integrated Circuit Development", 1 Feb. 1976 - 31 March 1976.

NR 383-032, TRW Systems, Inc., "TELD A/D Converter", I. I. - D. Claxton, N00014-76-C-

This work seeks to demonstrate that an A/D converter can be made to operate at clock rates in excess of 5 GHz. It uses GaAs TELDs and FETs on a common chip. A successive approximation approach is taken and active component count is about 10% of that of conventional architecture. Initially, 4 bits are to be developed.
Progress: New

Recent Publications: None

SYSTEM THEORY

NR 021-05-01, SYSTEM THEORY, (Dr. David K. Ferry, [illegible]

NR 375-002, University of California, Los Angeles, "New Error Bounding Techniques for the Evaluation of Communication System Performances," P.I. - Dr. K. Yao, N0001[illegible]

Two new bounding techniques and their applications to the evaluation of performances for large classes of communication systems will be investigated. The theory of moment space bounds and its application to the evaluation of error probability for digital communications will be investigated for the cases characterized by the presence of interference distortion. The use of a new optimal demodulator technique, developed in the minimum probability of estimation error sense, will be studied for performance in bandwidth expanding digital systems. Progress: New

NR 375-027, Texas Tech University, "Cumulants in Discrete Time Optimal Filtering and Control," P.I. - Dr. Stanley Liberty, N0001[illegible]

The research will utilize cumulants to develop a complete set of statistics on integral quadratic forms in Gauss-Markoff processes to obtain bounds on higher order statistics of the error energy in the optimal case. The cumulant formulation, developed by the principal investigator, allows a matrix difference equation formulation to be set up for a quadratic performance measure. Progress: An in-depth look has been taken at a complete statistical description of linear-quadratic-Gaussian (LQG) performance measures. The bound gives computationally tractable formulas that form the basis for better performance analysis. The complete statistical description of performance developed exhibits the essential properties of the LQG class of systems.

Recent Publications:

[illegible]

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[illegible], University of Pennsylvania, "[illegible]
[illegible]," [illegible], [illegible]

[illegible] will accomplish the [illegible] of [illegible]
[illegible] and integrated circuit [illegible] [illegible] the [illegible]
[illegible] analyses. Emphasis will be placed [illegible] [illegible]
[illegible]. Progress: Work accomplished in the past includes [illegible]
[illegible] which [illegible] have been derived in the [illegible]
[illegible] for finite [illegible] polynomials. [illegible] [illegible]
[illegible] relationship to fault analysis. The key [illegible] [illegible]
[illegible] from the graph model to a particular [illegible], which [illegible]
[illegible] fields have been used to model a class of [illegible]
[illegible] [illegible]. The use of [illegible] [illegible] [illegible]
[illegible] this to applications of fuzzy [illegible] and fuzzy [illegible].

[illegible], University of Pennsylvania, "[illegible] [illegible] [illegible]
[illegible] for Integrated Bipolar Junction Transistors," [illegible] [illegible]
[illegible], [illegible].

[illegible] will be aimed toward achieving analytical techniques [illegible]
[illegible] correlate large-signal transient and small-signal steady-state
performance of a broad variety of state-of-the-art integrated circuits
with certain of the key characteristics of the integrated [illegible]
[illegible]. In particular, the geometrical dimensions of the emitter, [illegible]
epitaxial collector, and N+ buried collector, the variation [illegible]
concentration, and the diffusion profiles in the base area [illegible] [illegible]
of independent variables for the transient and steady-state [illegible]
analyses [illegible] be considered. Progress: A closed-form solution [illegible]
Poisson's equation applied to the base-collector region [illegible]
bipolar device was developed. The solution comprises an extension [illegible]
to simplified analyses published elsewhere, and it leads to a [illegible]
physical definition of base pushout phenomena. However, the analytical
results evolve into practical suggestions for obtaining a high-level
simulation of gain and gain-bandwidth product characteristics.

Recent Publications:

[illegible], "A Large-Signal Model for the Transient [illegible]
in Integrated Bipolar Devices," IEEE [illegible], [illegible] [illegible],
[illegible].

[illegible], University of [illegible], [illegible], "Fault [illegible]
[illegible] Fault [illegible] [illegible] [illegible]," [illegible] [illegible]
[illegible], [illegible].

[illegible] will be [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]
[illegible] [illegible] [illegible]

[illegible] not only the current uncertainties of the system's physical parameters, but also the [illegible] nonlinear circuit theory. Devices such as the [illegible] variable, the [illegible], and the [illegible] will be the focal point of initial investigations. Progress: [illegible]

[illegible], Yale University, "Adaptive Control in Uncertain Systems and Control Theory," P.I. - Dr. K. S. Narendra, [illegible]

The work to be performed is concerned with theoretical questions of stability, effects of time-varying environments and the broad problem of applying adaptive algorithms of control by adaptive models applicable for non-linear processes. Practical applications of adaptive control processors and adaptive control of "dynamic" systems will be investigated. Progress: General schemes for the adaptive control and identification of multivariable systems where entire state vectors are accessible for measurement have been developed. A model reference approach is used, and Lyapunov's direct method is employed to ensure the convergence of these schemes. An added feature in the simplicity of the stable adaptive laws, which require explicitly only the error variables of the system and the plant and the system input. An extension has been developed for the case where only the system outputs are accessible, rather than all of the state variables. A unified approach to the synthesis of an adaptive observer is presented whereby the system state and parameters are simultaneously estimated.

Recent Publications:

1. Narendra, K. S. and Kudva, P., "Stable Adaptive Schemes for System Identification and Control - Parts I and II," IEEE Trans. on Systems, Man, and Cybernetics, Vol. [illegible], No. 6, November 1974.

2. [illegible], P. and Narendra, K. S., "Stable Direct Adaptive Control Schemes for Linear Systems," [illegible], Vol. [illegible], No. [illegible], December [illegible].

3. [illegible], P. and Narendra, K. S., "An Identification Procedure for Discrete Multivariable Systems," [illegible], Vol. [illegible], No. [illegible], October [illegible].

4. [illegible], P. and Narendra, K. S., "A New Approach to Adaptive Control," [illegible], Vol. [illegible], No. [illegible], [illegible].

5. [illegible], K. S., [illegible], P., "[illegible]," [illegible].

NR 377-972, Rensselaer Polytechnic Institute, "Detection Estimation, and Filtering of Signals in Impulse Noise," P.I. - Dr. James W. Modestino, N00014-75-C-0251

Efforts will be directed toward refining and extending previous impulsive noise modeling work in refining the MLF model and in modeling of impulse noise on communications networks and on FM threshold detection. Major effort will be expended in the determination of analytical performance bounds for both detection and estimating structures for these noise models. Progress: An analysis has been completed allowing exact calculation of the error probability performance of selected linear receivers operating in MLF impulsive noise environments. A study of the performance and properties of a number of coincidence detector structures has been completed. A coincidence detector is a suboptimum structure of the limiting variety which bases its decisions only on the polarity of the received data. A number of new numerical techniques have been developed for the evaluation of first and second order probability distributions of impulsive noise processes described as the linear combination of a low density shot process and background white Gaussian noise. A number of new results relating to adaptive detection in impulsive noise environments have been obtained.

Recent Publications:

1. J. W. Modestino, "Coincidence Procedures for the Detection of Known Signals in Statistically Undefined Background Noise," Technical Report No. 1, March 1975.

2. J. W. Modestino, "An Adaptive Detection Structure for Reception in Impulsive Noise Environments," Proc. 1975 International Conference on Communications, November 1975.

3. J. W. Modestino, "Adaptive Measurement Procedures," in Measurements, Data, and Noise, Ed. by S. Haykin and T. Kailath, Dowden, Hutchinson & Ross, Inc., Stroudsburg, Pa., 1976.

4. N00014-75-C-0251, Brown University, "Digital Processing of Biological Systems," P.I. - Dr. Richard Hahn, [illegible]

With the increasing complexity of [illegible] systems, there has been the need for sophisticated processing [illegible] in the electrical activity [illegible]. [illegible] has been accumulated, the [illegible] to be based on [illegible] what [illegible]

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In short, there is no theoretical foundation upon which general techniques can be developed. The object of this research is an attempt to develop such theoretical foundations. Present approaches are either local wherein the derivatives of the various external system parameters with respect to the component parameters are used to achieve the estimate or global wherein simulations of all possible faulty conditions are made prior to the test and compared with the measured external system parameters to achieve the desired estimates. This approach is based on the observation that the connections in a circuit or system define a type of valued function of a system valued variable, i.e., a mapping of the internal component parameters to the externally measured system parameters. Progress has been made in a number of areas. It has been shown that techniques for fault analysis in the analog area can be generalized to include the digital faults. To date it only includes the "Stuck-at-Faults." Nevertheless, this generalization is significant. In fault prediction, an ad-hoc algorithm has been proposed that does well. A minimum algorithm will be constructed and compared with the heuristic one.

References:

[1] [illegible], "The [illegible] Function [illegible]," [illegible] Circuit Theory and Application [illegible].

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